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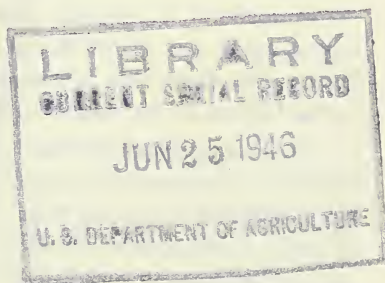
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FERTILIZERS AND LIME IN THE UNITED STATES

**RESOURCES
PRODUCTION
MARKETING
AND USE**



**Miscellaneous
Publication
No. 586**

UNITED STATES DEPARTMENT OF AGRICULTURE

THIS publication was prepared at the request of the Committee on National Fertilizers and Lime Policy of the United States Department of Agriculture and the War Food Administration—by Frank W. Parker, J. Richard Adams, K. G. Clark, K. D. Jacob, and A. L. Mehring, of the Division of Soils, Fertilizers, and Irrigation, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration—with assistance from the Agricultural Adjustment Agency, the Bureau of Agricultural Economics, and the Farm Credit Administration. It supersedes United States Bureau of Plant Industry, Soils, and Agricultural Engineering Plant-Food Memorandum Report II, Fertilizers and Lime in the United States, issued in March 1945.

It presents a factual review of data relating to resources, production, marketing, and use of fertilizers and lime, information of basic importance to all who are concerned with or interested in the formulation of a national policy in respect to these materials. A tabular appendix, a list of selected references, and lists of the illustrations and of the tables will be found on pages 73 to 93. Except as otherwise indicated, the years referred to are calendar years and the tons are short tons.

Washington, D. C.

Issued May 1946

FERTILIZERS AND LIME IN THE UNITED STATES

RESOURCES PRODUCTION MARKETING AND USE

NATIONAL welfare, particularly a healthy agricultural economy, depends on productive soils. Soils may be naturally fertile, or they may be naturally rather infertile and unproductive. Fertilizers and lime are often required to maintain the productivity of fertile soils and are extensively used to make relatively infertile soils profitable.

Despite the great importance of fertilizers and lime in the maintenance of a healthy, prosperous, and successful agriculture, relatively few people fully realize the part that these materials play in such segments of national affairs as agriculture, the mining and chemical industries, transportation, foreign trade, and labor. The interest of the farmer in fertilizers is more direct and seems more important than that of any other large group, yet many other groups—including labor, industry, and all consumers of food and fiber—likewise have a vital even though indirect interest in fertilizers.

FERTILIZERS AND LIME IN THE NATIONAL ECONOMY

A. Agriculture

1. Crop Production

The most obvious and probably the most striking effect of using fertilizer is that it increases crop production. In Alabama, for example, the production of seed cotton was increased from 415 pounds without fertilizer to 1,076 pounds with 975 pounds of a complete fertilizer, that is, a fertilizer containing all three elements—nitrogen, phosphorus, and potassium. Equally striking increases in yields of potatoes in Maine were obtained with 1,500 to 3,000 pounds per acre of a complete fertilizer. Experiments with wheat in Ohio show that yields can be doubled by proper use of fertilizers.

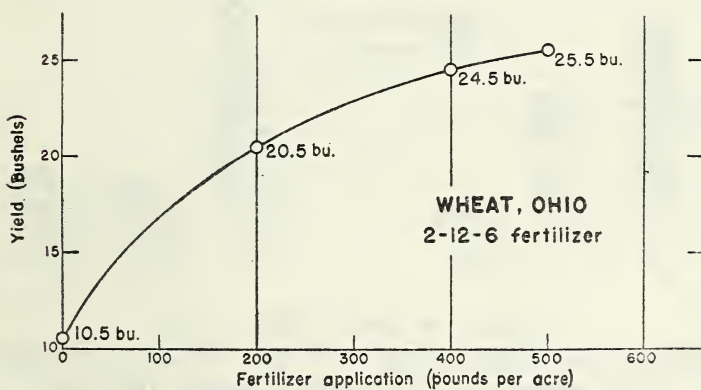
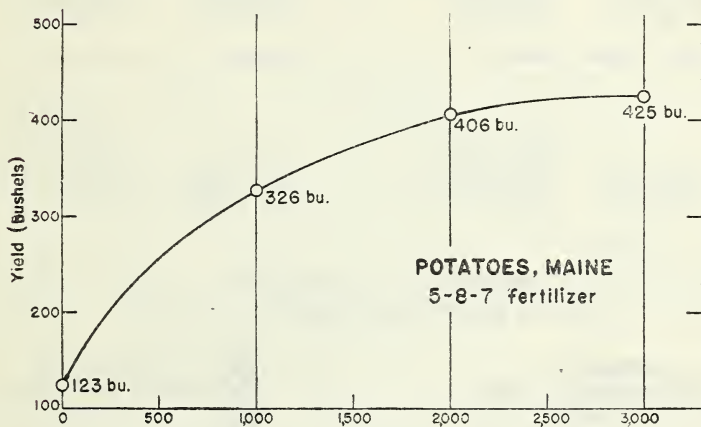
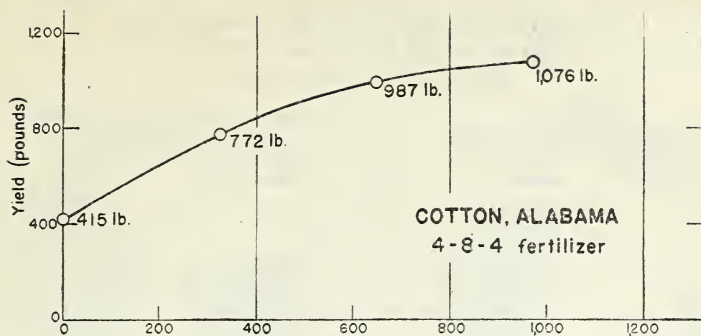
Such striking increases, however, are not realized in all sections of the country. In some sections the soils are still so fertile that there is little response to fertilizer application; in other sections rainfall or other climatic factors rather than plant nutrients limit the yields. The influence of different rates of fertilization on crop yields as determined in official experiments is shown on page 3.

The importance of fertilizers in crop production varies widely, in fact, in different parts of the United States. In the country as a whole, crop production attributable to the use of fertilizers was equal to about a fifth of the total crop production in 1944. In several States it was equal to half the total or more, while in many States it is a small or negligible factor. Its importance in different States and in the production of different crops is discussed in some detail on pages 16 to 30.

2. Soil Productivity and Improvement

The use of fertilizers is only one part of a good soil-management program, but in many sections it is a very important and essential part, as illustrated by the upper chart on page 4. This chart shows that fertilizers and continuous cropping, rotations, and liming, for instance, all had an influence on the yields of corn and wheat in a 30-year experiment on Wooster silt loam in Ohio. Both crops gave low yields when grown continuously year after year on the same land. Complete fertilizers greatly improved the yields. Yields likewise were improved when the crops were grown on limed land and in a rotation. The best returns, however, were obtained when rotations, liming, and the use of fertilizers were combined, and under these conditions the yields steadily improved. Analysis of the soils indicated that in many respects fertility was being increased by the better soil-management system.

That a great improvement in soil fertility results from the use of fertilizers in proper combination with other management practices is shown in the lower chart on page 4. A recent and as yet unpublished



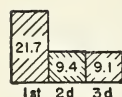
CROP RESPONSE TO COMPLETE FERTILIZER

EFFECT OF FERTILIZATION ON CORN AND WHEAT YIELDS IN CONTINUOUS CULTURE AND IN ROTATION ON WOOSTER SILT LOAM (OHIO)

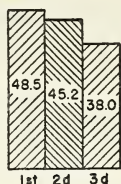
Average by 10-year periods

UNLIMED CORN, GROWN CONTINUOUSLY

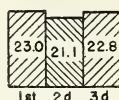
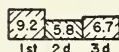
UNFERTILIZED
(bu. per acre)



FERTILIZED
(bu. per acre)

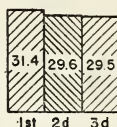


WHEAT, GROWN CONTINUOUSLY

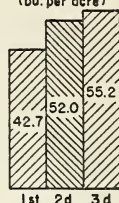


LIMED AFTER FIRST 10 YEARS CORN, 5-YEAR ROTATION

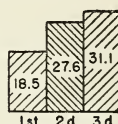
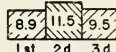
UNFERTILIZED
(bu. per acre)



FERTILIZED
(bu. per acre)

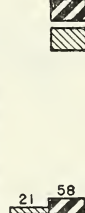


WHEAT, 5-YEAR ROTATION



INFLUENCE OF FERTILIZER ON THE PLANT-FOOD CONTENT OF SOILS

NORFOLK SOIL
CITRUS GROVES, FLORIDA
(lb. per acre)

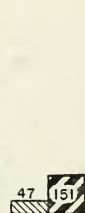


TOTAL
NITROGEN
(N)

AVAILABLE
PHOSPHATE
(P₂O₅)

AVAILABLE
POTASH
(K₂O)

CARIBOU SOIL
POTATO AREA, MAINE
(lb. per acre)



TOTAL
NITROGEN
(N)

AVAILABLE
PHOSPHATE
(P₂O₅)

AVAILABLE
POTASH
(K₂O)

TRENDS OF CROP YIELDS AND CHANGES IN PLANT-FOOD CONTENT OF SOILS UNDER LONG CROPPING, WITH AND WITHOUT USE OF FERTILIZER

survey of a fourth of the farms in Aroostook County, Maine, reveals that the soil used for the production of potatoes contains about three times as much available potash and phosphate as the virgin soil. Furthermore, the nitrogen and the organic-matter content have been maintained through the use of a rotation that includes a legume.

More striking effects of fertilizers have been observed in soils used for citrus production in Florida. Typical Norfolk soils from 14- to 20-year-old groves were found to contain almost 3 times as much available potash, 11 times as much available phosphate, and $1\frac{1}{2}$ times as much total nitrogen as the adjacent virgin soils. Similar great improvement in the nutrient status of soils has been found at many locations in regions where fertilizers are extensively used in the soil-management program. Thus fertilizers not only aid directly in crop production but are important in soil improvement.

3. Nutrition

Research and education have created an unusual interest in improving human nutrition. This involves the relations between soil fertility, the use of fertilizers, and the nutrition of man and animals. Although research in this field has been expanded by the Department of Agriculture and other agencies, many facts and relations remain to be developed, but some seem rather well established.

The quality of food and livestock feed is determined in large part by their content of protein, minerals, and vitamins. In human nutrition, deficiencies of calcium or of one or more vitamins are frequently observed. In animals, common deficiencies are protein, phosphorus, or vitamins. In both man and animals, deficiencies of the minor elements—notably iron, iodine, and cobalt—are not uncommon.

The use of fertilizer influences a crop's composition, but generally the change in the content of minerals, and particularly in vitamins, is not great. From the standpoint of nutrition, however, the change may be very significant. Probably the most important effect of fertilizers on feed crops is the change they produce or make possible in the type of crop grown. This is strikingly illustrated in the results of a pasture experiment in central Maine, as shown by the charts on page 6. Both treatments—lime, phosphate, and potash, and lime with complete fertilizer—more than tripled the production of forage and milk. These treatments also greatly altered the type of cover and the chemical composition of the forage by increasing the stand of clover and reducing the proportion of weeds. The lime, phosphate, and potash treatment favored the growth of white clover in comparison with grass and produced a forage nearly three times as rich in phosphorus and almost twice as rich in nitrogen (protein) and calcium as that from the untreated plot. The forage produced by the lime and complete fertilizer treatment was about 7 percent heavier than that from the lime, phosphate, and potash treatment, and although it contained much less clover and not quite so much phosphorus, nitrogen, and calcium as the latter, it produced 24 percent more milk, or nearly 4 times as much as the

MILK PRODUCTION
PER ACRE
FROM PASTURE



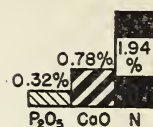
1025 pounds

VEGETATIVE COMPOSITION
AND DRY MATTER
PER ACRE



1220 pounds

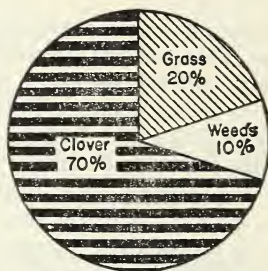
CHEMICAL
COMPOSITION
OF FORAGE



NO TREATMENT



3425 pounds



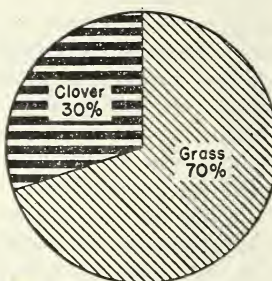
3942 pounds



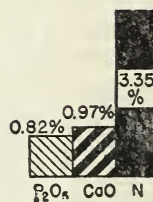
LIME, PHOSPHATE, AND POTASH



4250 pounds



4225 pounds



LIME AND COMPLETE FERTILIZER

INFLUENCE OF FERTILIZATION AND LIMING
ON THE YIELD AND CHEMICAL COMPOSITION
OF PASTURE IN CENTRAL MAINE

forage from the plot that had received neither lime nor fertilizer. Less striking differences are frequently obtained, but these data clearly indicate the important contribution that fertilizers can make to the improved nutrition of livestock and to the production of such protective foods as milk, meat, and eggs.

The fertilizer and soil management practices that are favorable to increased crop yields usually improve the nutritive value of the crop. It seems probable, therefore, that further work and recognition of the importance of the nutritive value of crops will increase the demand for fertilizers but will not materially alter present well-recognized good soil-fertility practices.

4. Erosion Control

The control of soil erosion is a well-recognized national problem. Fertilizers and lime can be very effectively utilized in the erosion-control program in two ways.

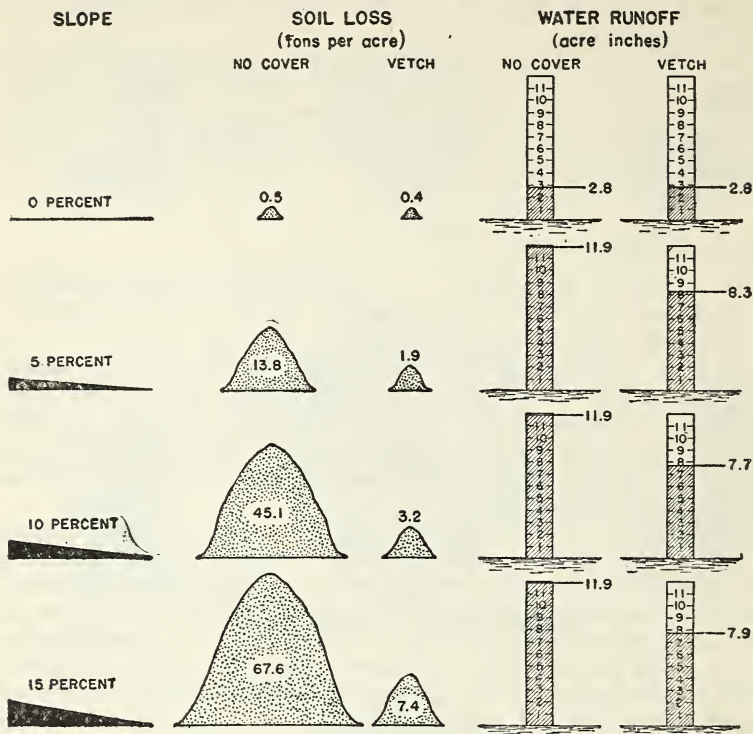
First, by increasing crop yields on less erodible lands fertilizers reduce the need of cultivating easily erodible fields. The latter can then be placed in pasture or other crops that greatly reduce the erosion hazard. This method of using fertilizers for erosion control can be effectively utilized by most of the farmers who are confronted with this problem in the Eastern States.

The second method involves the use of fertilizers and lime on grass or cover crops to promote rapid vegetative cover on erodible land. The cover crops reduce erosion by binding the soil, increasing infiltration of rainfall, and slowing the runoff. The contribution that a good cover crop can make toward erosion control is shown by the upper chart on page 8, based on data from experiments on Cecil clay in Alabama.

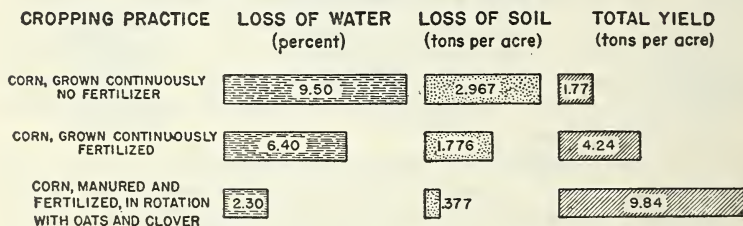
When the slope of the clay in these experiments varied from 0 to 15 percent, the loss of soil in a single winter and spring season varied from 0.5 to 67.6 tons per acre on bare land. A good vetch cover crop reduced the maximum loss to 7.4 tons per acre. As an average, the cover crop on the 5-, 10-, and 15-percent slopes reduced soil loss by 90 percent and the water runoff by $3\frac{1}{2}$ to 4 inches. The vetch in this experiment was well fertilized, and the use of fertilizer is usually essential for the production of a good cover crop. In other Alabama experiments, for example, 400 pounds of superphosphate per acre increased the green weight of vetch from 3,474 to 10,795 pounds per acre as an average for 1 to 3 years at four locations. Lime with superphosphate increased the yield to 15,692 pounds.

The importance of fertilizers and rotations in reducing water runoff and soil erosion as well as improving yields is illustrated by an experiment on Bath silt loam in New York, the results of which are shown in the lower chart on page 8. The comparison was between corn grown year after year without fertilizer, corn grown every year and fertilized with 200 pounds of a complete fertilizer each year, and corn in a 3-year rotation with oats and clover. Six tons of manure and 500 pounds

INFLUENCE OF SLOPE AND FERTILIZED COVER CROP ON SOIL EROSION AND WATER RUNOFF DURING WINTER AND SPRING SEASON IN ALABAMA



EFFECT OF FERTILIZATION AND ROTATION ON CROP YIELDS AND ON LOSSES FROM BATH SILT LOAM 20 PERCENT SLOPE (NEW YORK)



SOIL EROSION AND WATER LOSSES AS INFLUENCED BY SLOPE, CROP COVER, AND FERTILIZATION

of superphosphate were applied in the rotation. Fertilizers alone reduced soil losses 40 percent and more than doubled the yields. The combination of rotation, manure, and fertilizer reduced erosion on the corn plots about 90 percent and increased the yields from 1.77 to 9.84 tons per acre.

Such research data clearly indicate the importance of using fertilizers in a well-balanced erosion-control program. It should be emphasized that such a program requires many interrelated measures, as terracing, strip cropping, contour farming, and vegetative cover. Adequate use of fertilizers and lime should not be considered a "cure-all," but should be combined with other sound practices.

It is evident from the foregoing that fertilizers and lime are very important to American agriculture and to the American farmer. They are essential for satisfactory crop production, for the maintenance and improvement of soil fertility, for the proper nutrition of man and livestock, and for a well-balanced program of soil-erosion control.

B. Industry and Labor

The chemical industry is deeply interested in the production and distribution of fertilizers. In many cases the production of both fertilizers and fertilizer materials is closely integrated with other phases of the industry.

I. Nitrogen

About one-third of our fertilizer nitrogen is a byproduct of the steel, coke, and gas industries. This byproduct had a value of about 20 million dollars in 1943, and almost a million tons of sulfuric acid (basis 50° B.) was used in its manufacture. Byproduct organic-nitrogen fertilizers are obtained from many industries and ordinarily furnish more than 10 percent of the fertilizer nitrogen.

The production of synthetic nitrogen fertilizer is integrated with other phases of the chemical industry, including the production of plastics, alkali, explosives, synthetic alcohol, and dyes. This contributes to the efficient operation of plants and lowers the production costs of nitrogen fertilizers. In some cases it makes possible the use of low-cost raw materials and thus minimizes seasonal peaks in plant operation. In prewar years only about a third of the synthetic nitrogen produced in domestic plants was used as fertilizer. An even smaller percentage of total plant production went for that purpose because synthetic alcohols and other products were produced in the same plants and by substantially the same equipment as that used in making synthetic ammonia. These proportions may change materially under post-war conditions, but there is little doubt that such integration and diversity of products tend to reduce the cost of producing nitrogen fertilizers.

2. Phosphates

The production of phosphatic fertilizers is related to the production of phosphate chemicals and the sulfuric acid industry. Other phases of the chemical industry, however, are not related so closely to the production of fertilizer phosphates as they are to the production of synthetic nitrogen fertilizers. Almost one-fifth of the phosphate used in the United States in prewar years was for nonfertilizer purposes, but fertilizer manufacturers produced only small quantities of chemical-grade materials.

The fertilizer industry used about 30 percent of the domestic production of sulfuric acid in 1941. The major uses were $2\frac{1}{2}$ million tons (basis 50° B.) in the manufacture of superphosphates and 960,000 tons in the production of ammonium sulfate. The acid used in the manufacture of superphosphates was obtained from three sources—about 30 percent as a byproduct of copper and zinc smelting, 10 percent as spent acid from petroleum or chemical industries, and 60 percent as virgin acid from sulfur or pyrites.

Although the phosphate industry is closely related to the sulfur and sulfuric acid industries, superphosphate manufacture can be readily conducted as a separate operation, and few economies are effected by correlating its production with other parts of the chemical industry.

Information is not available on the number of employees and the pay roll of superphosphate plants, but it is available for the phosphate-rock industry. The 33 companies that operated 40 phosphate-rock mines in 1939 employed 3,750 persons. Their pay rolls amounted to \$3,700,000, and products were valued at \$12,300,000.

3. Potash

The potash industry sells 90 percent of its production to agriculture and about 10 percent to the chemical industry. Certain producers also market borax, salt cake, and other chemicals; but considered as a whole, potash production is not closely integrated with other parts of the chemical industry. The industry employed 1,800 persons in 1939, paid \$3,650,000 in salaries and wages, and produced materials valued at nearly \$14,000,000.

4. Mixed Fertilizers

In 1939, 764 establishments were primarily engaged in the manufacture of commercial fertilizers and superphosphates and nearly all of them manufactured mixed fertilizers. They employed 24,100 persons, had a pay roll of \$23,400,000, and sold products valued at \$185,700,000. Fertilizers were distributed by more than 50,000 agents or dealers.

5. Liming Materials

Although information on the agricultural liming materials industry is not so complete as that on the fertilizer industry, it can be said that

the production and distribution of liming materials involves thousands of workers and millions of dollars in pay rolls and investments. Besides the persons engaged full time, there is considerable part-time employment in small operations scattered over much of the country.

Though much of the liming material is produced directly for agricultural purposes, there is a large and growing production of byproduct and waste liming materials from other industrial operations. Limestone is by far the most important liming material, but only a comparatively small part of the total output is consumed in agriculture. In 1943, for example, the production of limestone (crushed and broken stone) totaled 128,750,000 tons, of which the largest use (43 percent) was in concrete and as aggregate in road building; the second largest (25 percent) was as flux in furnace operations; while its use in agriculture ranked third (11 percent).

6. Freight Movement

The distribution of some 8,300,000 tons of commercial fertilizer to farms in 1940 involved the following estimated freight movement of raw materials and intermediate and finished products:

<i>Carrier</i>	<i>Shipment (tons)</i>	<i>Transportation charges</i>
Rail	22,209,000	\$36,277,000
Water	5,163,000	8,863,000
Truck	10,121,000	7,883,000
Total	37,493,000	52,883,000

Transportation charges, therefore, averaged \$6.36 for each ton of finished product, or almost one-fifth the average retail price. This movement and the rather high freight cost result from the fact that most fertilizer raw materials come from considerable distances—potash from California and New Mexico, sulfur from Louisiana and Texas, 80 percent of the phosphate from Florida, and large quantities of nitrogen from the East Central States.

The foregoing data indicate that the fertilizer and lime industries are an important segment of American business; that they provide direct or indirect employment to tens of thousands of men, represent an investment of hundreds of million dollars, and deal with important natural resources.

FERTILIZER CONSUMPTION

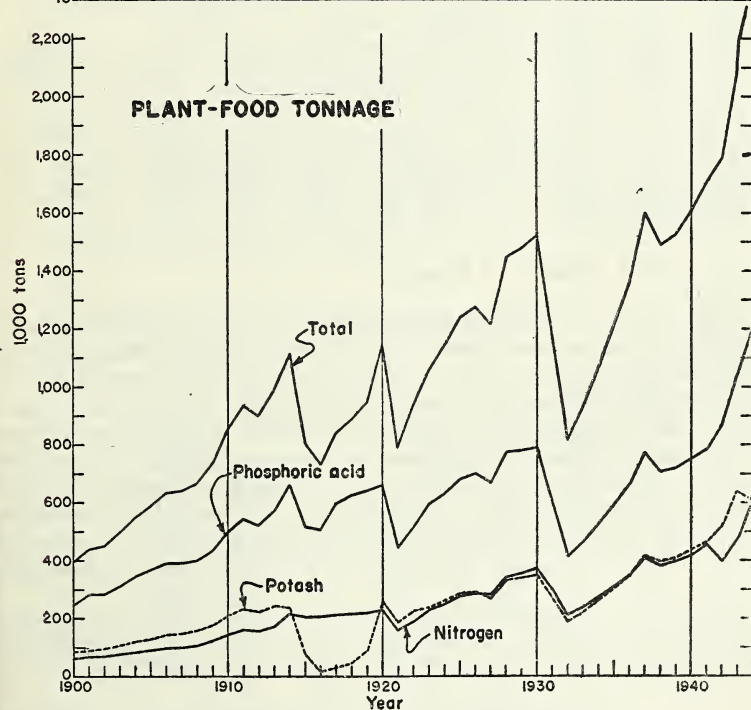
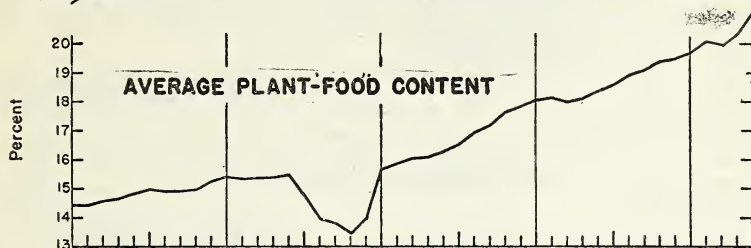
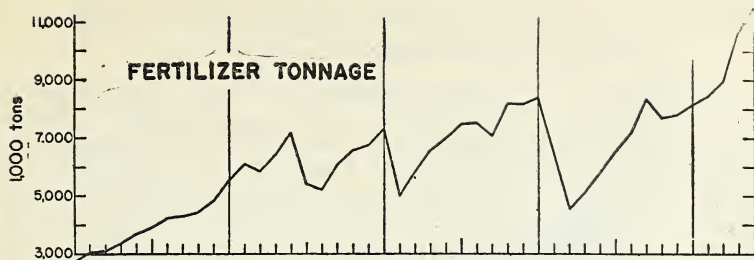
A. Commercial Consumption, 1900 to 1944

The commercial consumption of fertilizers in the United States, including Hawaii and Puerto Rico, increased from 2,730,000 tons in 1900 to 10,733,000 in 1943, and to an estimated 11,568,000 in 1944. (See chart, p. 13, and table 12, p. 81). In the period 1900 to 1943 the plant-food content of the average ton increased from 14.5 to 20.4 percent. The plant-food tonnage, therefore, went from 394,700 tons in 1900 to 2,193,700 tons in 1943, an increase of 456 percent. In 1900 the average rate of fertilizer application on cropland was only 2.8 pounds of plant food per acre. The rate increased to 5.6 pounds in 1920 and to 12.2 in 1943.

As the use of fertilizer increased, the proportion, or ratio, of the three major plant foods showed substantial changes. In 1900 the nitrogen (N)—phosphoric acid (P_2O_5)—potash (K_2O) ratio was 1.0–4.0–1.4; in 1920 it was 1.0–2.9–1.1; and in 1941 it had changed to 1.0–1.7–1.0. The nitrogen and potash content of fertilizers materially increased, whereas the content of phosphoric acid changed very little.

Total plant-food consumption increased steadily from 1900 to 1914, when it reached a maximum of 1,115,000 tons. World War I caused a decline in consumption, so that the 1914 level was not reached again until 1920. After a drop in 1921, consumption of plant food increased to a new maximum of 1,523,200 tons in 1930. Consumption then dropped 45 percent by 1932, and the 1930 level was not reached again until 1937 in the case of nitrogen and potash, and not until 1942 in the case of phosphoric acid. Maximum prewar consumption was 458,100 tons N (1941), 792,800 tons P_2O_5 (1930), and 464,800 tons K_2O (1941). The impetus of the war increased consumption of all three plant foods materially, and there is no doubt that if there had been greater supplies the 1943 and 1944 consumption would have exceeded the levels indicated. There was a decided shortage of nitrogen, rather adequate supplies of phosphate for commercial distribution, and some shortage of potash.

United States consumption of plant food from 1935 to 1937 exceeded that of any other nation except Germany. As an average of three prewar years, this country consumed 13.8 percent of the nitrogen, 17.1 percent of the phosphate, and 13.9 percent of the potash used as fertilizer in the world. We were the largest consumers of phosphates and ranked second in the consumption of both nitrogen and potash. Plant-food consumption per acre of arable land in eastern and southern States is similar to that in western Europe.



FERTILIZER CONSUMPTION

B. Distribution Through Government Aid, 1935 to 1944

1. Tennessee Valley Authority

Government distribution of fertilizers was begun in 1935 as part of the test-demonstration farm program of the Tennessee Valley Authority (TVA) and cooperating agricultural colleges. In this program the fertilizer manufactured by the TVA is furnished the cooperating farmer without cost, except for the expenses of transportation and certain items of program operations. The farmer also agrees to keep the necessary records and assist in showing visitors the results obtained on his farm. The growth of the program and its scope in 1943 are shown by the data in the charts on page 15.

The tonnage of fertilizer distributed, largely double superphosphate,¹ increased from 1,986 tons in the fiscal year 1935 to 42,435 in the fiscal year 1944. The number of participating farms showed a corresponding increase from 984 to 31,542 in this period. In recent years the average farm received about 1.3 tons of TVA fertilizer each year. It would appear that this quantity might be inadequate for effectively fertilizing the soil-conserving crops on farms that probably have an average of 50 to 60 acres each in cropland and pasture.

The program for the fiscal year 1944 included 27,073 farms in the seven Tennessee Valley States (Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia) and 4,469 farms in 21 other States. The fertilizer materials distributed included 30,926 tons of double superphosphate, 971 tons of calcium metaphosphate, 552 tons of fused phosphates, 9,453 tons of ammonium nitrate, and 423 tons of ammonia liquor.

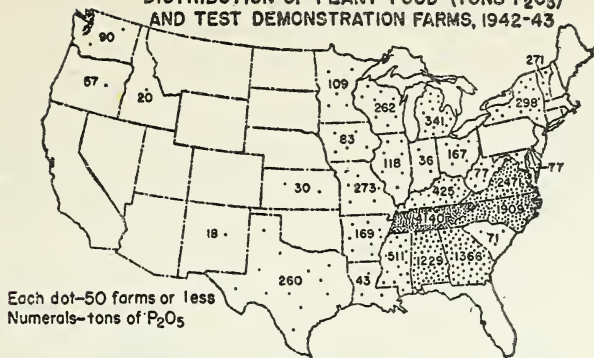
2. Agricultural Adjustment Agency

Beginning with 1936, the agricultural conservation programs of the Agricultural Adjustment Agency (AAA) have included encouragement for the use of phosphate and potash on soil-conserving crops. Initially this encouragement largely took the form of cash payments to farmers who bought and used the phosphate or potash in specified ways. Later this was supplemented by a program of advancing material to farmers in lieu of payments and, more recently, further supplemented in some States by a purchase-order plan. Superphosphates, chiefly ordinary superphosphate,² comprised a very high percentage of the tonnage of fertilizer advanced to farmers for use principally on hay, pasture, and

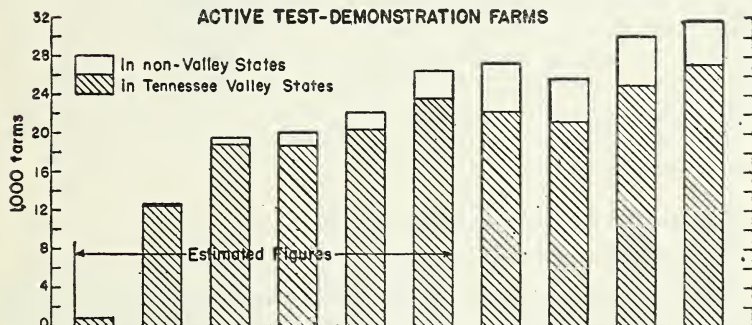
¹ The term "double superphosphate," which is synonymous with the terms "triple superphosphate" and "treble superphosphate," refers to the product, usually containing about 45 to 50 percent of available P_2O_5 , made by treating phosphate rock with phosphoric acid.

² The term "ordinary superphosphate," which is synonymous with the terms "normal superphosphate" and "standard superphosphate," refers to the product, usually containing 18 to 20 percent of available P_2O_5 , made by treating phosphate rock with sulfuric acid.

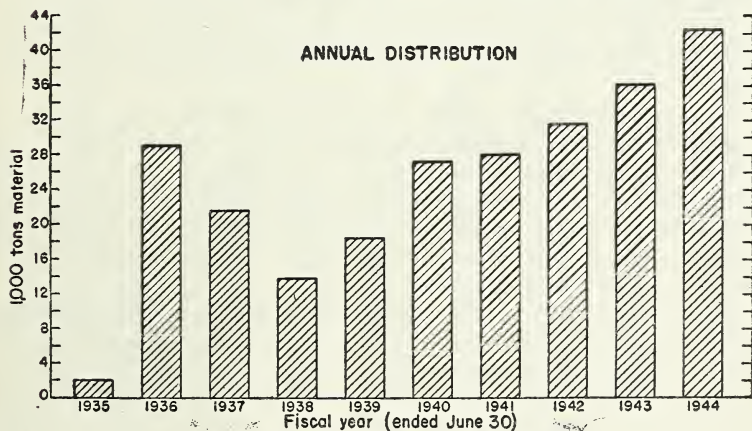
DISTRIBUTION OF PLANT FOOD (TONS P_2O_5) AND TEST DEMONSTRATION FARMS, 1942-43



ACTIVE TEST-DEMONSTRATION FARMS



ANNUAL DISTRIBUTION



DISTRIBUTION OF FERTILIZER BY THE TENNESSEE VALLEY AUTHORITY

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cover crops. Phosphate-potash mixtures, potash salts, borax, and other materials, however, also have been included.

State participation has varied in accordance with the need for plant food in a State in relation to other conservation practices. Some States have participated in the program more extensively than others, as is clearly indicated for the 1942 program year in the map on page 17. The program for that year covered the use of 1,073,304 tons of 20-percent superphosphate equivalent on 8,001,626 acres of 716,484 farms in 48 States. The average use for each farm, therefore, was 1.5 tons on 11.2 acres, or 268 pounds per acre (53.6 pounds of available P_2O_5), a good rate of application for most soil-conserving crops.

The chart on the lower part of page 17 shows that the total tonnage of fertilizer on which aid was given by AAA increased from 244,750 tons in the 1936 program year to 1,954,946 tons in the 1943 program year. The periods during which materials were supplied under a given program designation were not the same in each State or area. The 1936 to 1942 program years for each State comprised periods ranging from 9 to 12 months, mostly in the corresponding calendar year. The 1943 program year included more than 12 months in practically all States, ending generally December 31, 1943. For this reason the data for the 1943 program year are not directly comparable with data for previous program years.

C. State and Regional Consumption

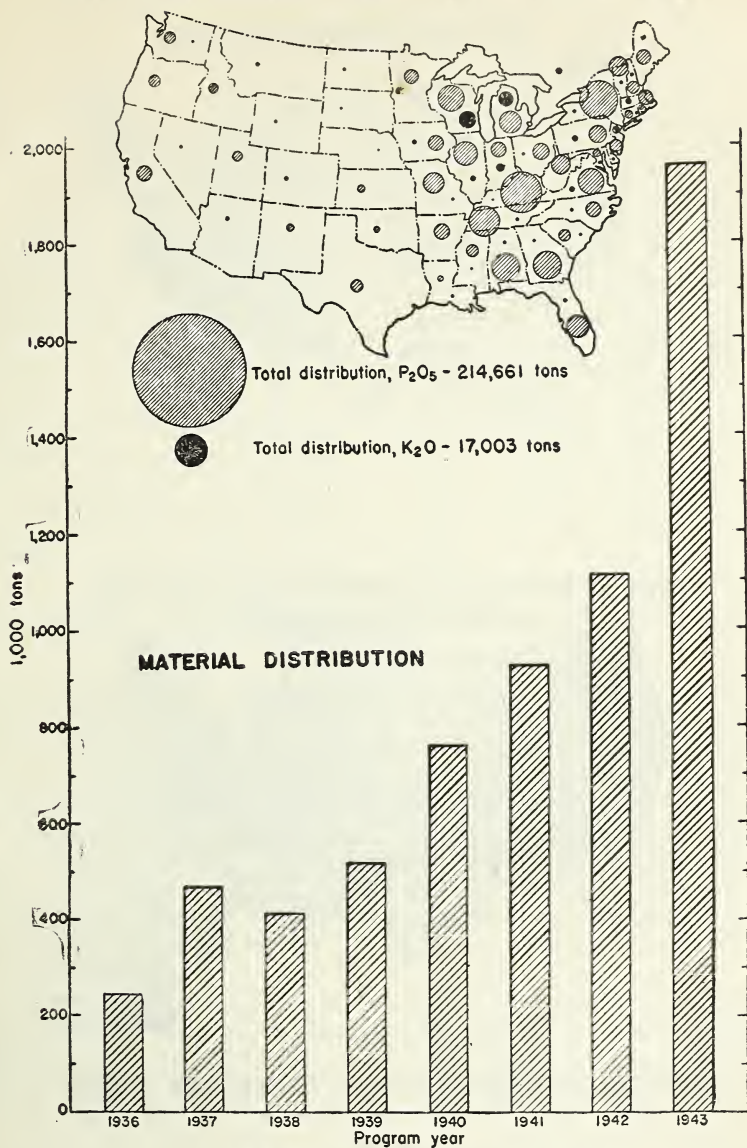
I. Fertilizer Consumption by States

About 75 percent of the total consumption of fertilizer in 1943 (map, p. 18, and table 13, p. 82) was in New England and the Middle Atlantic and Gulf Coast States from Virginia to Louisiana. Consumption in the great agricultural areas of the Central States is relatively small. The reasons for such regional differences are discussed on pages 26 to 32.

An even better index of the intensity of fertilizer consumption is the quantity of plant food used per acre of cropland. In 1941 the consumption varied from less than 1 pound per acre in the West North Central States to more than 50 pounds in New England and the South Atlantic States, exceeding 100 pounds per acre in Florida, New Jersey, and Rhode Island, and ranging from 50 to 100 pounds in six States and from 25 to 50 pounds in six others.

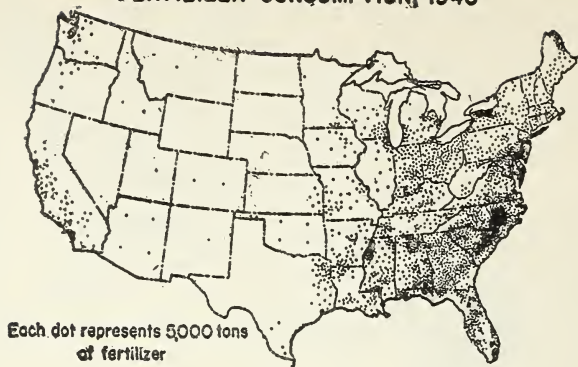
The foregoing data permit comparisons with consumption in Europe in the prewar years 1935 to 1937, data for which are given in table 1 for comparison with similar data in the map on page 18. These indicate that use of fertilizers in the Netherlands is somewhat more intensive than in Florida. In Germany the rate per acre is similar to that in Maine and in New Jersey. Our South Atlantic States generally use more than France, the United Kingdom, Norway, Sweden, or Italy. The rates in Austria, Czechoslovakia, and Finland are about the same as in Indiana.

PLANT-FOOD DISTRIBUTION IN THE 1942 AGRICULTURAL CONSERVATION PROGRAM

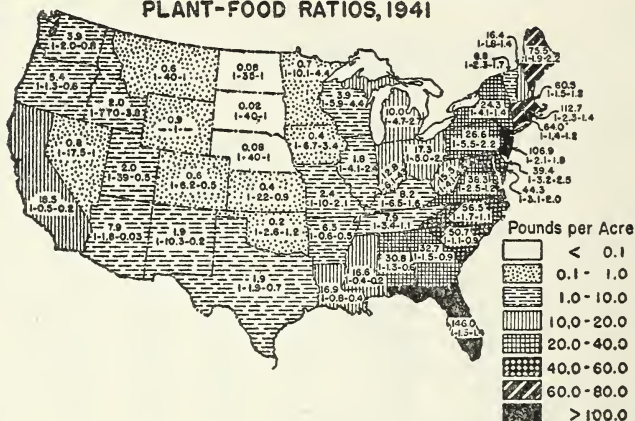


**DISTRIBUTION OF FERTILIZER
BY THE AGRICULTURAL ADJUSTMENT AGENCY**

FERTILIZER CONSUMPTION, 1943



AVERAGE PLANT-FOOD CONSUMPTION PER ACRE AND PLANT-FOOD RATIOS, 1941



DISTRIBUTION PATTERNS OF FERTILIZER USAGE

TABLE 1.—*Plant-food consumption in Europe, average 1935 to 1937*

Country	Average plant-food consumption per acre of—		Plant-food ratio ¹		
	Arable land	Arable land plus permanent meadows and pastures	N	P ₂ O ₅	K ₂ O
	<i>Pounds</i>	<i>Pounds</i>			
Netherlands.....	300	129	1.0	1.6	2.7
Germany.....	96	67	1.0	1.0	1.7
United Kingdom.....	53	14	1.0	3.6	1.5
Denmark.....	47	40	1.0	1.7	.8
Norway.....	39	32	1.0	2.0	2.1
France.....	33	21	1.0	2.3	1.7
Sweden.....	30	23	1.0	1.8	1.7
Italy.....	24	17	1.0	1.9	.1
Finland.....	18	14	1.0	3.7	1.7
Czechoslovakia.....	15	11	1.0	2.0	1.1
Austria.....	12	6	1.0	2.5	1.7
U.S.S.R. (Russia).....	3	1	1.0	2.8	1.1
Hungary.....	2	2	1.0	4.4	.5
Rumania.....	.1	.1	1.0	6.9	.8
Bulgaria.....	(²)	(²)	.....	.....	.....

¹ The proportions of phosphoric acid and potash to that of nitrogen.

² Consumption less than 0.1 pound per acre.

Ohio, and Michigan. Lower rates prevail in Bulgaria, Hungary, and the Soviet Union, but doubtless many of these countries should be using more fertilizer to improve production and living standards.

In the continental United States in the fiscal year ended June 30, 1943, 11,305,945 tons of fertilizers were used on a fifth of the crop acreage (table 13, pp. 82 and 83). Of this total 1,254,000 tons, or more than 11 percent, were distributed directly by the TVA and the AAA. The total distribution for which government agencies were responsible, however, was somewhat larger than this, since a considerable tonnage of material on which AAA aid was given was obtained through commercial channels.

With the exception of Puerto Rico and Hawaii, the South Atlantic States used fertilizer on the largest proportion (78 percent) of the total crop acreage of any region, and the West North Central States the least (3 percent). Among the individual States Florida ranked highest in this respect (87 percent) and South Dakota lowest (0.1 percent).

In the fiscal year 1943 the percentage of plant food per ton of commercial fertilizer varied from an average of 24.40 in the New England States to 18.33 in the South Atlantic region. The South Central States used 65,897 tons of nitrogen separately and only 45,067

TABLE 2.—*Plant-food consumption by regions, 1941*

Region	Total consumption in all fertilizer			Proportion of total consumption in mixed fertilizer			Plant-food ratio ¹		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
	1,000 tons	1,000 tons	1,000 tons	Percent	Percent	Percent			
New England ²	18.4	31.9	32.0	79.1	80.9	88.8	1.0	1.8	2.0
Middle Atlantic.....	39.7	151.1	71.0	80.3	62.0	93.9	1.0	2.9	2.1
South Atlantic.....	176.8	269.1	184.2	55.1	83.0	80.3	1.0	2.3	1.5
East North Central.....	24.5	126.6	76.3	71.3	86.3	95.8	1.0	6.3	4.2
West North Central.....	2.1	22.7	5.5	76.3	37.3	89.6	1.0	5.4	3.1
South Central ³	112.8	125.6	56.9	33.2	66.1	80.7	1.0	2.2	1.2
Western.....	44.9	40.0	10.7	19.4	30.4	79.1	1.0	1.4	1.0
Territories.....	34.4	13.0	24.4	42.0	76.3	65.8	1.0	.7	1.1
Total, United States....	453.6	780.0	461.0	49.3	72.5	84.9	1.0	2.5	1.8
Continental United States.....	419.2	767.0	436.6	49.9	72.5	86.0	1.0	2.7	1.8

¹ See footnote 1, table 1.² State fiscal year 1940-41 for New Hampshire, Massachusetts, and Rhode Island.³ State fiscal year 1940-41 for Alabama, Arkansas, Louisiana, Oklahoma, and Texas.

tons in mixed materials; likewise the Western States used more nitrogen in separate materials—34,426 tons separately and 13,063 as mixed fertilizers. Also, more phosphoric acid was sold in separate materials in the West North Central and Western States than in mixed goods. Otherwise, most of the plant food in commercially distributed fertilizers was used as mixed material. Regional data for the tonnage of commercially distributed plant food consumed in the calendar year 1941 are summarized in table 2 to show the major regional differences in the last year before shortages influenced consumption.

About 50 percent of the nitrogen, almost 75 percent of the phosphoric acid, and 85 percent of the potash is used in mixed fertilizers. The division of the plant-food tonnage between mixed goods and materials varies widely among regions. The South Atlantic, South Central, and Western States, as well as the Territories, use a high proportion of their fertilizer nitrogen as separate materials. The Western and West North Central States use about 62 to 70 percent of their phosphate as separate materials, but in all other regions from 62 to 86 percent of the phosphate is used in mixed fertilizers. All regions of continental United States use 79 percent or more of their potash in mixed fertilizer.

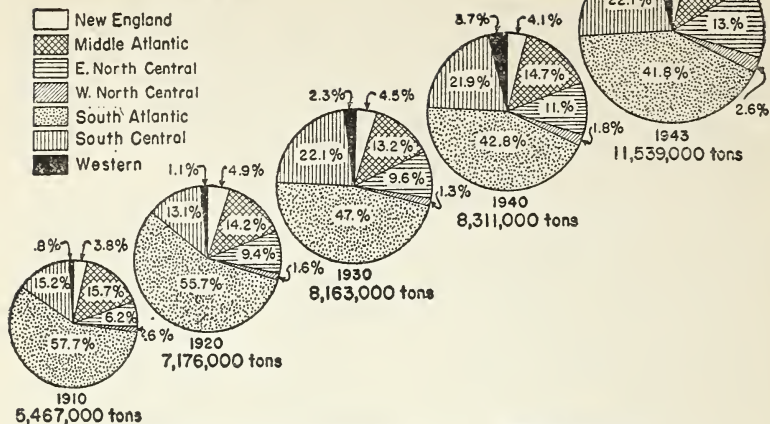
Just as the use of mixed fertilizers and separate materials varies from region to region, so does the plant-food ratio, that is, the proportions of phosphoric acid and potash to that of nitrogen. The Territories and the Western, New England, South Central, and South Atlantic States use a low proportion of phosphoric acid in relation to nitrogen. The proportion of both phosphoric acid and potash is high in both the East and West North Central States. The plant-food ratio for each State is shown in the map on page 18. The wide differences in plant-food ratios reflect differences in soil requirements and cropping systems. Together with wide variations in the use of mixed fertilizers and separate materials, they indicate great differences in plant-food requirements and fertilizer practices as well as in the flexibility of the industry to meet farmer demands.

2. Trends in Consumption

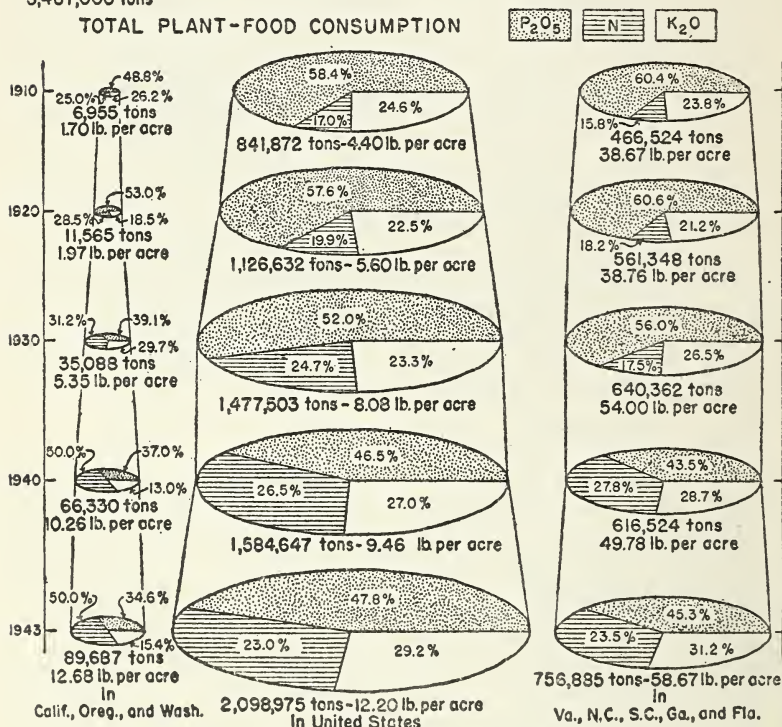
Regional trends show a most rapid increase in total fertilizer consumption (including both commercial and governmental distribution) in the Western, East North Central, West North Central, and South Central States. (See charts, p. 22, which are based in part on the data of tables 13, p. 82, and 14, p. 84.) Since 1910 total consumption in the Western and West North Central States has increased nearly tenfold, as compared with a 53-percent increase in the South Atlantic States. It may be expected that these trends will continue. Consumption may increase on the Atlantic seaboard and in the Southeast, but the greatest rate of increase, if not the greatest tonnage increase, will probably come in the East North Central, West North Central, and Western States.

Trends in plant-food consumption and in the proportion of the three major plant foods for the continental United States and two contrasting

FERTILIZER CONSUMPTION BY REGIONS



TOTAL PLANT-FOOD CONSUMPTION



TRENDS IN FERTILIZER CONSUMPTION

regions—Western and South Atlantic—are shown in the charts on page 22. Although the national trends were discussed on pages 12 to 16, these charts illustrate the increased use of both nitrogen and potash in respect to phosphoric acid in the period 1910 to 1943. The increase is most marked in the case of nitrogen. A similar change has occurred in both the South Atlantic and the Western States.

Considering the 30-year period 1909 to 1939, the percentage of farmers using fertilizer has declined in New England, remained fairly constant in the Middle and South Atlantic States, and materially increased in all other regions. (See table 15, p. 85.) Most of the increase occurred in the period 1909 to 1919 and probably reflects the agricultural prosperity and high demand for fertilizers associated with the first World War. All this increase was retained in subsequent years, and substantial increases followed in the South Central and Western States. These data suggest that farmers who began to use fertilizers in recent years as a result of war conditions may continue to do so. If that is the case, the pattern of fertilizer use in the coming years may be substantially different from that in the prewar years. It would be difficult, however, to evaluate the magnitude of such a change.

D. Consumption by Crops

In the period 1929 to 1942, the pattern of fertilizer consumption by crops changed markedly in respect both to the tonnage and to the proportion of the total fertilizer used on a crop, as is shown by the data in table 16, page 86, which include materials distributed by governmental agencies for the years 1938 and 1942.

The quantity of fertilizer used on cotton decreased from 28.0 percent of the total consumption in 1929 to 19.3 in 1938 and to 14.6 in 1942. Thus the relative quantity used on cotton in 1942 was only 52 percent of that used in 1929. Smaller decreases have occurred in the proportion of the total fertilizer tonnage used on tobacco and potatoes. The proportionate use on small grains has shown very little change, but the use on corn has increased slightly. On the other hand, the proportionate use of fertilizer on vegetable and fruit crops, taken together, was 62.5 percent greater in 1942 than in 1929.

Hay and pasture received only 165,000 tons of fertilizer, or 2.1 percent of the total tonnage in 1929. This, of course, does not include the much larger tonnage that was used on wheat and clover seedings. The proportionate consumption of fertilizer on hay and pasture increased to 6.2 and 12.9 percent in 1938 and 1942, respectively. The quantity of fertilizer used on hay and pasture was 1,288,700 tons in 1942, six times that in 1929.

CONSUMPTION OF LIMING MATERIALS

Data on the consumption of liming materials in the United States prior to 1929 are much less complete than those for fertilizers. The statistics in Yearbooks of the Department of Agriculture indicate the annual use of about 1.2 million tons of liming materials in 1916 to 1918. Consumption apparently increased to about 2.2 and 2.6 million tons in 1925 and 1928, respectively. These data are incomplete and for 1925 and 1928, at least, are probably 1 million tons below actual consumption.

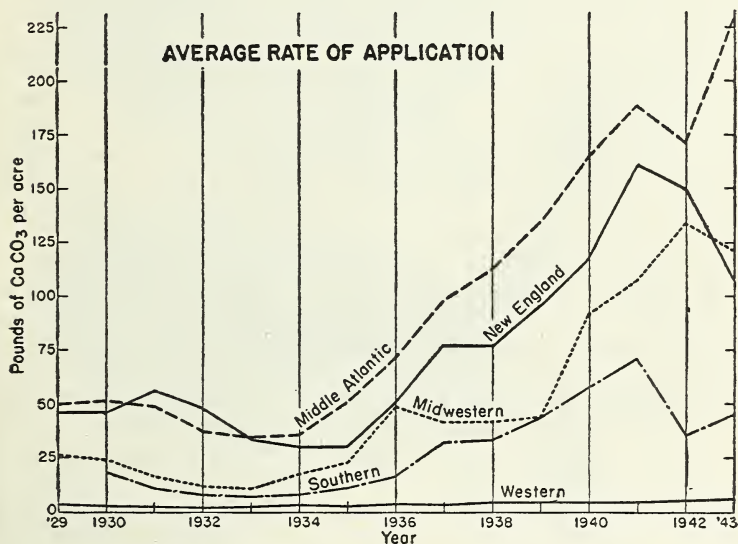
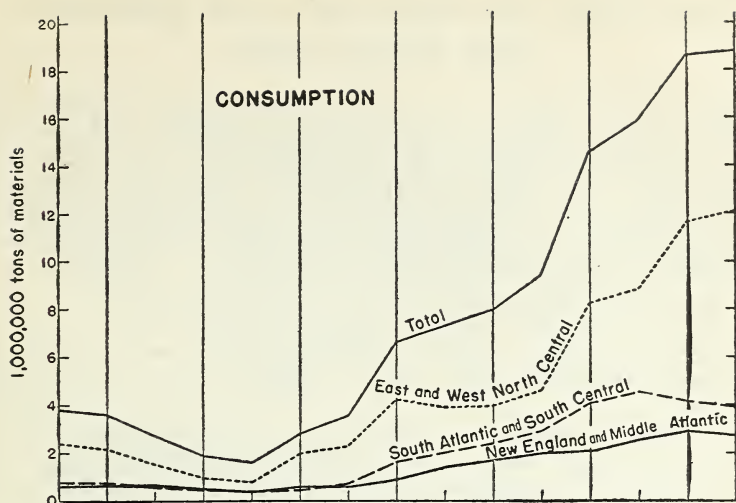
Lime consumption declined from 3.8 million tons in 1929 to 1.8 million in 1932 and 1.6 million in 1933. (See table 17, p. 86, and the upper chart, p. 25.) Although it had risen to near predepression levels by 1935, it was not until 1936, when its use was included in the AAA agricultural conservation program, that consumption of liming materials increased significantly. Total consumption reached 7.9 million tons in 1938, 15.8 million tons in 1941, and 18.8 million tons in 1943. Data on the calendar-year basis are not available in respect to the total tonnage of liming materials on which AAA aid has been given. In the 1943 program year,³ 951,374 farmers in 38 States were credited under the AAA program with applying a total of 19,030,163 tons of liming materials to 11,182,294 acres, or an average of 1.7 tons to the acre.

Consumption trends by regions are shown in the graphs on page 25, both on the basis of total tons of liming materials and on the basis of consumption of calcium carbonate per acre of total cropland.⁴ With the exception of the Western States, all regions have experienced a great increase in consumption of liming materials. In 1929 and 1930 the use of lime was a rather well-established practice in New England and the Middle Atlantic States. Consumption was at a rate equivalent to about 50 pounds of calcium carbonate per acre of cropland, not including pasture. If pasture acreage were included, the average rate would be reduced about 30 percent. In recent years three of the five regions have achieved a lime use equivalent to 125 to 225 pounds per acre per year. Consumption in the Southern States is still relatively low. Continued progress in these States is essential before it will be advisable to discontinue the use in mixed fertilizers of such liming materials as dolomite. Consumption of lime has been low in the Pacific Coast States and, as compared with the East, the need for lime is low.

³ The 1943 program year included more than 12 months in practically all States, ending generally December 31, 1943.

⁴ Consumption chart on p. 25: Source of data and States constituting the various regions are given in table 17, on pp. 86 and 87.

Rate-of-use graph: Data are from the National Lime Association. The constituent States of the various regions: *New England and Middle Atlantic*, same as those in table 17, pp. 86 and 87. *Midwestern*: Ohio, Ind., Ill., Ky., Mich., Wis., Minn., Iowa, Kans., Mo. *Southern*: Va., N. C., S. C., Fla., Tenn., Ala., Miss., Ark., La. *Western*: Calif., Oreg., Wash.



REGIONAL CONSUMPTION AND RATE OF APPLICATION OF LIMING MATERIALS

(See footnote in text for constituent States of the regions)

FACTORS INFLUENCING THE DEMAND FOR FERTILIZERS

A good understanding of the basic reasons for the regional and annual variation in fertilizer consumption is necessary to the formulation of a program designed to rationalize fertilizer usage. The five major factors influencing consumption are believed to be (1) native soil fertility, (2) the farming system, (3) farm income, (4) fertilizer prices, and (5) research and education. Each of these factors is here considered in some detail.

A. Native Soil Fertility

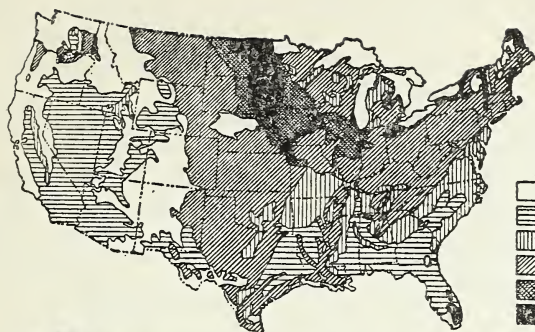
Other things being equal, more fertilizer would be used on relatively infertile than on fertile soils. Soils in the different parts of the United States exhibit great differences in fertility. They also vary widely in their content of nitrogen, phosphoric acid, and potash, as indicated by the maps on page 27. In the South Atlantic and Gulf Coast States, for example, the soils are relatively low in all three of the major plant foods. By way of contrast, in Minnesota, Iowa, and a large part of Illinois, Indiana, and Ohio they contain much more of each.

Differences in fertility are the result of many factors. Climate is one of the most important. Native vegetation and the parent material from which the soils are formed likewise are important. In addition to variations in the total quantity of plant nutrients, there may be important differences in their availability to crops. Thus two soils may contain the same total quantity of phosphate or potash but differ widely in the quantities readily available. Still other factors not discussed here also influence the fertility of soils.

The relation between native fertility of soils and fertilizer consumption is indicated by a comparison of the maps on pages 18 and 27. The fertility of our soils is changing. These changes must be determined and considered in any program designed to implement a national fertilizer policy. Soil fertility has been greatly increased by the use of fertilizers and good management in Maine and Florida. (See chart on p. 4.) Similar improvements have been made in other States. On the other hand, many of our better soils are being gradually depleted of their fertility. Some of them are still so fertile that they do not respond to fertilizer application. An increasing proportion of the soils in some of our best agricultural regions, however, are showing good responses. This is particularly true with the introduction of potentially higher yielding varieties of crops.

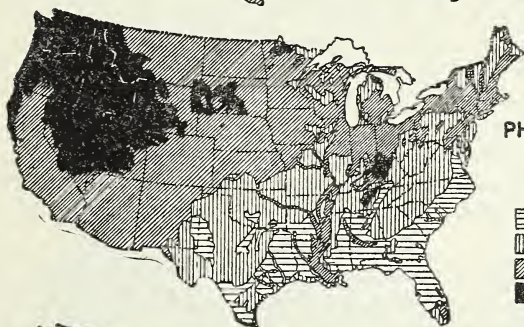
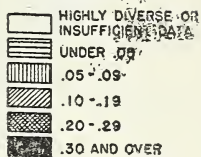
B. The Farming System

The farming system has a great influence on the requirement and use of commercial fertilizer. In a grain, legume hay, and livestock sys-



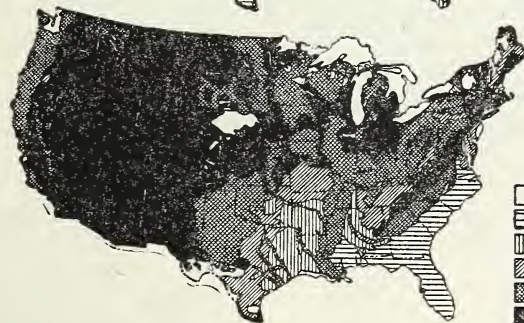
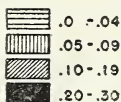
NITROGEN

PERCENT N



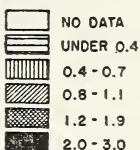
PHOSPHORIC ACID

PERCENT P_2O_5



POTASH

PERCENT K_2O



PLANT FOOD IN SURFACE FOOT OF SOIL

tem, crop residues and farm manure, if properly utilized, substantially reduce commercial-fertilizer requirements. In fact a large part of the nitrogen needed to maintain productivity may be obtained from the legume. This situation contrasts markedly with a cash-crop system, where there is almost clean cultivation and crop removal with little or no opportunity for the return of plant nutrients in manure and crop residues or through green manuring practices. To offset this disadvantage, the cash crops—potatoes, tobacco, and cotton—usually have a sufficiently high acre value to warrant the larger expenditures for commercial fertilizer necessary to maintain and increase production.

The proportion of farm income derived from livestock and livestock products in 1941 ranged from 87.5 percent for Wisconsin to 6.85 for Rhode Island (map, top of p. 29). In the same year, acre values of crops were \$79.86 for California and only \$8.94 for South Dakota (map, bottom of p. 29). Generally, those States that receive most of their income from livestock produce crops with a relatively low acre value. As would be expected, therefore, such States generally use less fertilizer than States in which the livestock industry is not so important and in which the average acre value of crops is higher. (Compare charts, p. 18, and maps, p. 29.)

A recent study indicates that about 80 percent of the variation in average rate of nitrogen fertilization in 25 eastern States may be attributed to differences in (1) the average nitrogen content of the soil, (2) the average acre value of crops, and (3) the proportion of income from livestock.

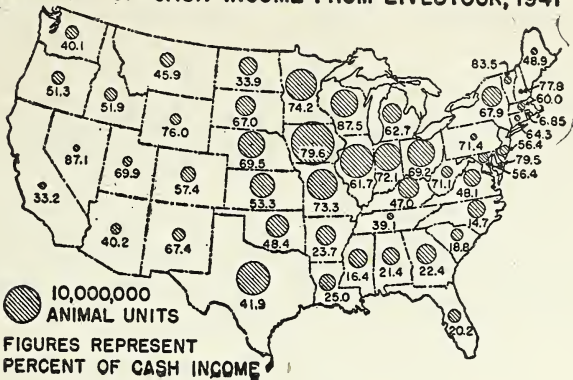
Manure provides an enormous source of plant food for use on row crops and hay land in States that have a large livestock industry. In the East North Central States, where 70 percent of the farm income in 1941 was from livestock, almost 90 percent of the total plant food was

TABLE 3.—*Plant-food content of manure and fertilizer used on crops in several regions and certain States in these regions, 1941*

Region and State	Proportion of income from livestock	Estimated plant food from manure	Plant food from fertilizer
	<i>Percent</i>	<i>Tons</i>	<i>Tons</i>
New England.....	63	90,000	82,300
Massachusetts.....	60	8,400	14,200
Middle Atlantic.....	67	500,000	249,700
New York.....	68	225,000	83,100
East North Central.....	70	900,000	227,200
Ohio.....	69	175,000	86,900
Iowa.....	79	260,000	4,100
South Atlantic.....	21	50,000	848,300
North Carolina.....	15	6,100	177,100
Georgia.....	22	8,500	143,100

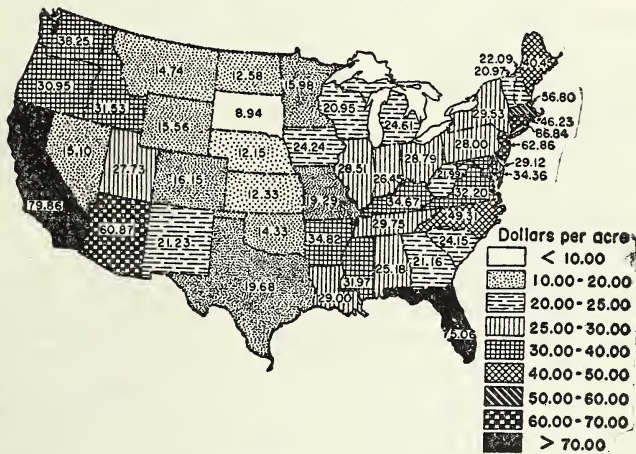
10,000,000 ANIMAL UNITS

FIGURES REPRESENT PERCENT OF CASH INCOME



Dollars per acre

- < 10.00
- 10.00-20.00
- 20.00-25.00
- 25.00-30.00
- 30.00-40.00
- 40.00-50.00
- 50.00-60.00
- 60.00-70.00
- > 70.00



29.

supplied by manure. In contrast, the South Atlantic States, with only 21 percent of their income derived from livestock, had to depend on commercial fertilizers for more than 94 percent of the plant food used (table 3). In a number of States—New York, Pennsylvania, Iowa, Wisconsin, and others—farm manure alone supplies more plant food than the total consumed in both manure and commercial fertilizers by such large consumers of commercial fertilizers as North Carolina and Georgia. The farm manure used in 22 northern States contains about 2.1 million tons of plant food, almost 25 percent more than all the commercial fertilizer consumed in 1941. Naturally, the use of this quantity of plant food in manure influences the consumption of commercial fertilizer.

The acre value of crops has a great influence on fertilizer use. In general, such high-acre-value crops as truck crops, potatoes, tobacco, and citrus are fertilized at rates that almost eliminate plant nutrients as a factor limiting production. On the other hand, fertilizer use is limited on low-acre-value crops (table 4).

TABLE 4.—*Crop acreage and fertilizer use in relation to crop value per acre*¹

Crop group	Proportion of cropland in indicated crops	Proportion of fertilizer used on indicated crops	Index numbers of acre use of fertilizer (all crops = 100)	Index numbers of acre value of crops (all crops = 100)
	<i>Percent</i>	<i>Percent</i>		
Vegetables.....	0.83	7.10	863	681
Fruits and nuts....	1.89	8.75	462	509
Intertilled field crops.....	44.54	67.03	150	129
Small grains.....	33.47	13.32	40	74
Hay.....	19.27	3.80	20	60

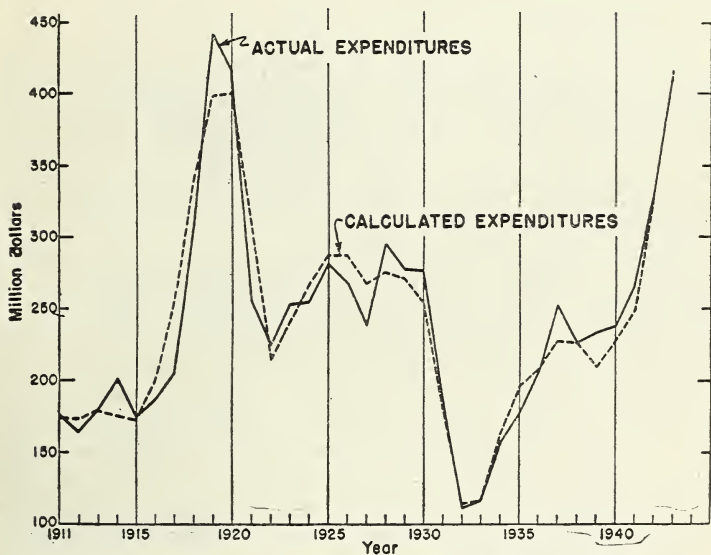
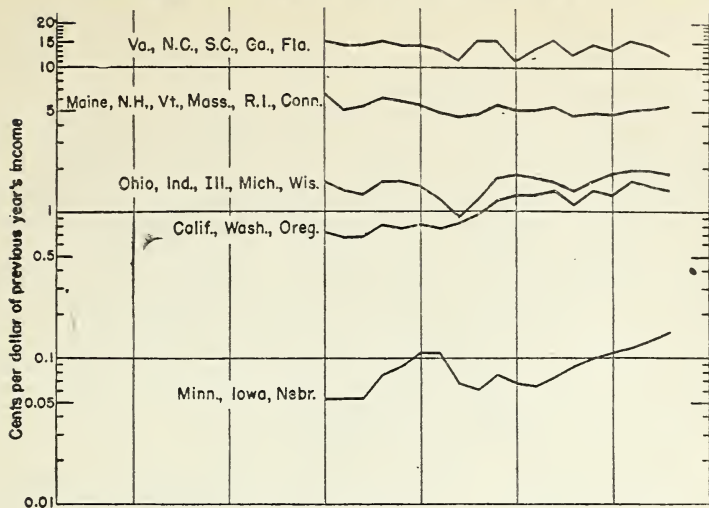
¹ Average for 1924, 1928, 1932, and 1936.

Vegetable crops receive 7.10 percent of the fertilizer but occupy only 0.83 percent of the cropland. The index of fertilizer consumption for vegetables is 863; for intertilled field crops, 150; and for hay, 20. The corresponding indexes of crop value are 681, 129, and 60. Therefore, the farming system, including the growth of legumes and the use of manure, affects the fertilizer consumption to a considerable extent, since the practice is to fertilize most heavily those crops that yield the greatest financial return per acre.

C. Farm Income

Recent studies, showing the rather close relationship between farm income and expenditures for fertilizer, indicate that variations in farm income accounted for at least 90 percent of the variation in the expendi-

REGIONAL LEVELS AND TRENDS OF FERTILIZER EXPENDITURES



RELATION BETWEEN FARM INCOME AND EXPENDITURES FOR FERTILIZERS

tures for fertilizer in the period 1911 to 1943. (See charts, p. 31.) The calculated expenditures for fertilizer were based on (1) the previous year's cash farm income from crops and Government payments, (2) the current year's income from the same sources, and (3) the proportion of the previous year's income remaining after the expenses of crop production were deducted.

The level of expenditure in relation to farm income varies in different regions. (See upper chart, p. 31.) Farmers of the South Atlantic States each year spend for fertilizer about 14 percent of their previous year's total cash farm income from crops, livestock, and Government payments. The corresponding figure for New England is 5 percent and for the East North Central States, 1.6 percent. There is a very definite upward trend in the Pacific Coast States—from 0.7 percent in 1925 to 1.5 in 1941. Except in the Pacific Coast and West North Central States the level of fertilizer expenditure in relation to cash farm income has been rather constant since 1925 and the national level has been constant since 1911. In the period from 1911 to 1943, American farmers spent annually for fertilizer an average of 2.68 ± 0.04 percent of their previous year's total cash farm income.

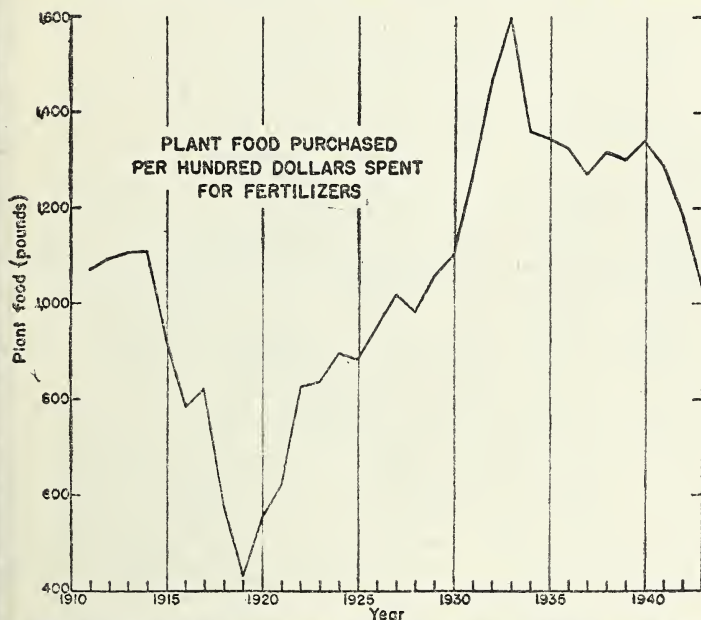
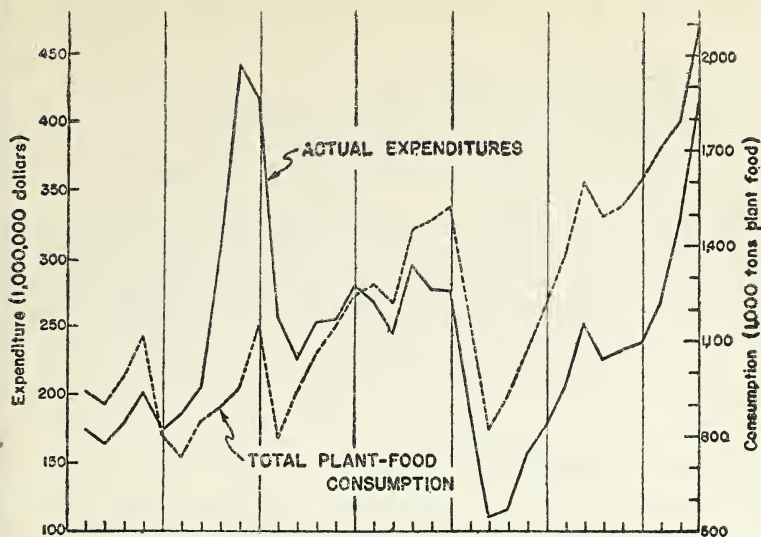
These relationships make possible a rather good estimate of fertilizer expenditures that would be made under different levels of farm income in the next few years.

D. Fertilizer Prices

The fact that the percentage of farm income expended for fertilizer has been substantially constant for more than 30 years indicates that dollar demand, rather than price level or agronomic requirements, has been the most significant factor in determining commercial plant-food consumption. For a given dollar demand, therefore, the price level at which fertilizer is available has an important effect on the quantity of plant food purchased for use.

An examination of the trends in expenditures for fertilizer, in the consumption of plant food, and in the changes in fertilizer prices from 1911 to 1943 indicates not only that consumption of plant food tends to increase during periods of falling prices, as in the period from 1919 to 1930, when the dollar demand also was decreasing, but also that plant-food consumption may increase in the face of rising prices, if the pressure of dollar demand is sufficiently great, as in the periods from 1915 to 1919 and from 1933 to 1943. The controlling effect of dollar demand over price level is shown in the periods from 1920 to 1921 and from 1930 to 1933, when decreases in dollar demand so far overbalanced price reductions that plant-food consumption decreased. (See charts, p. 33.)

In each of the years 1921, 1924, and 1937, farmers spent approximately 253 million dollars for fertilizer. For this expenditure they received 791,000, 1,141,000, and 1,601,500 tons of plant food, respectively. As compared with 1921 they received 44 and 102 percent more



**THE RELATION BETWEEN EXPENDITURES FOR FERTILIZER
AND PLANT-FOOD CONSUMPTION**

plant food in 1924 and 1937. The average fertilizer in 1937 contained a higher proportion of nitrogen, the highest priced plant nutrient, than in 1921. In 1932, expenditures for fertilizer dropped to 111 million dollars, but that sum purchased slightly more plant food than the 255 million dollars in 1921.

The quantity of plant food obtained from the expenditure of \$100 has varied from 429 pounds in 1919 to 1,597 pounds in 1933. In the period from 1925 to 1929 it averaged 980 pounds, but from 1935 to 1939 it was 1,310 pounds.

Fertilizer expenditures and plant-food consumption in the second World War afford a striking contrast to the situation in 1918 and 1919. In 1919 farmers spent 441 million dollars for 948,000 tons of plant food. In 1943, with a smaller expenditure—404 million dollars—they obtained 2,192,800 tons, or more than twice as much plant food.

Fertilizer prices are considered in detail on pages 38 to 45, and methods are suggested for further reducing the cost of plant food on the farm.

E. Research and Education

It might appear that the four factors—native soil fertility, farming system, farm income, and fertilizer price—influence fertilizer consumption to such a degree that research and educational programs have little effect. Such is not the case. State and Federal research and educational work, as well as that conducted by the fertilizer industry and other private agencies, have markedly influenced the last three of these four factors and thereby have influenced fertilizer consumption. They have contributed to the more efficient use of fertilizers as well as to the production of fertilizers of decidedly better grade. Some of the outstanding achievements are the work on fertilizer placement, the use of high-analysis fertilizers, the use of secondary and minor elements, including magnesium and boron, the formulation of non-acid-forming fertilizers, and the diagnosis and control of deficiency diseases of crops.

The final objective of all research and educational work in the fertilizer field is more economical production of crops of better quality in a stable soil-conserving farming system. Research, therefore, is necessarily directed toward reducing the cost of production of fertilizers and developing improved materials for fertilizer use. It is also designed to accomplish a better understanding of the action of fertilizers in soils and on crop production and to determine the types, quantities, and methods of application for the different soil types in respect to climatic conditions and to the crop to be grown. Education on the other hand gets the research findings into practice. It includes such widespread activities as publication of scientific and popular articles, farm demonstration programs, subsidy grants for approved practices, and "yardstick" operation of manufacturing facilities. Sometimes achievement of the goals tends to reduce, but generally it increases, fertilizer consumption.

ESTIMATES OF POSTWAR DEMAND FOR FERTILIZERS AND LIME

A. Commercial Demand

The quantity of fertilizer that farmers would purchase at different levels of farm income can be estimated on a historical basis from the data discussed on pages 30 to 32 and on other considerations. During periods of depression it is estimated that only 7.8 million tons of fertilizer, containing 1.56 million tons of plant food, would be purchased. With no unemployment, purchases by farmers would exceed the prewar maximum of 1941 by 56 percent and would amount to 13.2 million tons, containing 2.64 million tons of plant food. The average cost of a ton of fertilizer would range from \$32 during years of considerable unemployment to \$38 if there was no unemployment. Such estimates, based on the degree of unemployment and on indicated levels of farm income and fertilizer prices, are given in table 5.

TABLE 5.—*Estimated fertilizer and plant food that would be purchased by farmers under certain circumstances*

Item	Full employ- ment	Some unemploy- ment	Consider- able unem- ployment
Gross farm income.....million dollars...	¹ 20,000	15,000	10,000
Expenditure for fertilizer.....do.....	500	375	250
Average cost of fertilizer....dollars per ton..	38	35	32
Fertilizer purchased ².....1,000 tons....	13,200	10,700	7,800
Plant-food content.....do.....	2,640	2,140	1,560
Nitrogen (N).....do.....	686	556	406
Phosphoric acid (P ₂ O ₅).....do.....	1,241	1,006	433
Potash (K ₂ O).....do.....	713	578	421

¹ The comparable figure for 1945 is approximately \$23,880,000,000.

² Assumed composition: N, 5.2 percent; P₂O₅, 9.4; K₂O, 5.4.

If the developments that are indicated in the section on retail prices (pp. 41 to 45) take place, purchases of plant food under full employment would probably approximate 810,000 tons of nitrogen, 1,340,000 tons of phosphoric acid, and 850,000 tons of potash. The increase would be equivalent to 1.8 million tons of fertilizer and would make purchases 77 percent greater than in 1941.

No satisfactory basis has been developed for estimating the quantity of liming materials that farmers will be likely to purchase under different levels of farm income.

B. Estimates of Profitable Use

The foregoing estimates of the quantity of fertilizer farmers may purchase are lower than the quantity it would be profitable for them to use under the assumed conditions. Only on the high-acre-value crops does the present average rate of fertilizer use closely approach the quantity that gives the maximum return per acre. For many field crops, only a small percentage of farmers use rates as high as recommended by the State authorities. It should be remembered, however, that the law of diminishing returns is operative and therefore that there is less incentive for the farmer to use the higher rates. (See charts, p. 3.)

In considering the long-time outlook for fertilizer consumption it is desirable to have estimates of the quantity of plant food it would pay farmers to use. Such estimates, based on suggested postwar crop acreages under conditions of agricultural prosperity, have been prepared in production-adjustment studies by the United States Bureau of Agricultural Economics and cooperating State committees, which include representatives of the agricultural experiment stations and the extension service.

In formulating the estimates, prepared with a few indicated exceptions by the State committees, the assumption was made that fertilizer use would be at the most economic level consistent with the 1940 prices for fertilizers and approximately 85 percent of the 1943 prices for farm products. (See tables 6, p. 37; 18, p. 87; and 19, p. 88.)

The suggested over-all crop acreage for the postwar period was only 2.6 percent more than for the year ended June 30, 1943. Only tobacco, sugarcane and sugar beets, and sweetpotatoes were assigned acreages more than 10 percent greater than in the base period. The suggested acreages of large-seeded legumes and of corn, however, were 29.9 and 8.7 percent less, respectively.

The estimates indicate that increased tonnages of plant food could be used profitably on all crops in the postwar period. The total estimated profitable annual use under the assumed conditions is equivalent to an increase of 130.8 percent over the quantity used in 1942-43. Even for the crops now most heavily fertilized—tobacco and potatoes—the estimated profitable use of plant food is 48.0 and 55.4 percent more. For cotton, sweetpotatoes, corn, and sugarcane and sugar beets the increases are 63.3, 98.2, 115.1, and 169.3 percent, in that order. The increases for small grains and for hay and pasture are 207.4 and 313.8 percent, respectively, of the 1942-43 practice, and those for all other crops average 59.7 percent.

The 5,303,361 tons of plant food that it is estimated could be used profitably each year in the postwar period under conditions of agricultural prosperity includes 1,085,976 tons of nitrogen, 2,715,979 of phosphoric acid, and 1,501,406 of potash (table 18, p. 87). On the same basis as for fertilizers, the total quantity of liming materials that it is considered farmers could profitably use in the postwar period is es-

timated to be approximately 51,400,000 tons. This is an increase of 175 percent over consumption in 1942-43. (See chart, p. 25, and table 17, p. 86.)

It is evident that the use of the estimated quantity of fertilizer on the indicated acreage would result in a very substantial increase in agricultural production as compared with that of the 1943 fiscal year (table 19, p. 88). The magnitude of the increase for individual crops could be estimated readily. On the whole, it seems likely that production would be some 10 to 20 percent above that for 1942-43.

TABLE 6.—*Estimated crop acreage and estimated profitable annual use of plant food in the United States in the postwar period under conditions of agricultural prosperity compared with data for the year ended June 30, 1943*

Crop	Acreage			Plant food		
	Used in 1942-43	Estimated for postwar ¹	Increase	Used in 1942-43	Estimated for postwar ¹	Increase
	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>Percent</i>	<i>Tons</i>	<i>Tons</i>	<i>Percent</i>
Corn.....	97,092	88,602	-8.7	504,662	1,085,654	115.1
Cotton.....	21,930	23,295	6.2	320,228	522,927	63.3
Tobacco.....	1,450	1,835	26.6	107,061	158,406	48.0
Potatoes.....	3,420	3,462	1.2	184,036	285,954	55.4
Sweetpotatoes....	902	1,003	11.2	32,402	64,233	98.2
Large-seeded legumes ²	24,589	17,230	-29.9	61,867	153,609	148.3
Sugarcane and sugar beets....	1,133	1,413	24.7	19,649	52,923	169.3
Small grains ³	117,193	126,429	7.9	336,909	1,035,665	207.4
Hay and pasture..	431,245	455,070	5.5	305,703	1,265,021	313.8
All other crops ⁴ ..	47,209	47,199	0	425,201	678,969	59.7
Total ⁵	746,163	765,538	2.6	2,297,718	5,303,361	130.8

¹ Preliminary figures subject to revision; compiled from estimates furnished the Bureau of Agricultural Economics by the State production adjustment committees, except for Illinois, North Dakota, and South Dakota. Fertilizer use assumed to be at the most economic level consistent with 1940 prices for fertilizers and 85 percent of 1943 prices for farm products.

² Soybeans, cowpeas, peanuts, and dry beans.

³ Wheat, oats, barley, rye, and buckwheat.

⁴ Fruits, nuts, rice, seed crops, and vegetables.

⁵ Not including the District of Columbia.

FERTILIZER PRICES

A. Wholesale Price of Fertilizer Material

The trends of wholesale prices of the more important fertilizer materials, expressed in dollars per unit (20 pounds) of plant food except in the case of phosphate rock and sulfur, are shown in the charts on page 39. Other price data are given in table 20, page 89.

1. Nitrogen

Nitrogen prices dropped from wartime levels by 1921 and then changed very little until about 1927. With the development of the domestic synthetic nitrogen industry and the great expansion of the industry in other countries nitrogen prices dropped appreciably. The decrease was further accelerated by the depression, so that in 1932 the wholesale price of nitrogen in ammonium sulfate was \$1.02 per unit, equivalent to \$20.90 per ton of material, with some sales as low as \$16 to \$18. Prices of chemical nitrogen recovered slightly in the period 1932 to 1938 but changed little in the next 6 years. They are currently about 55 percent of the 1925 price.

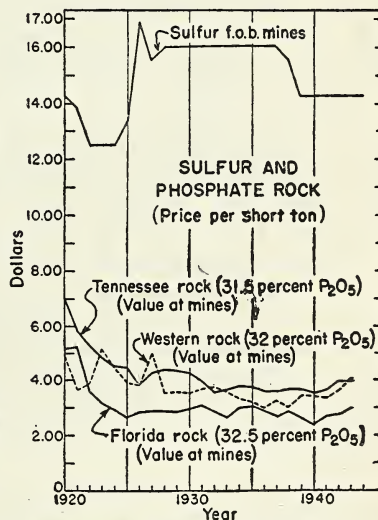
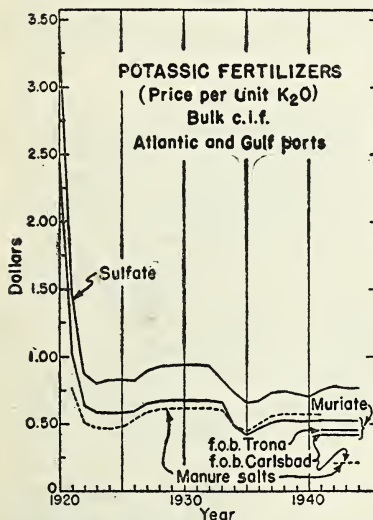
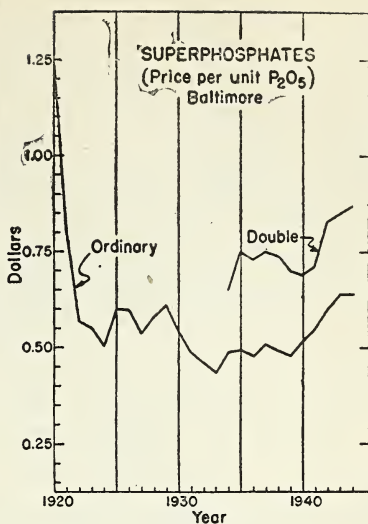
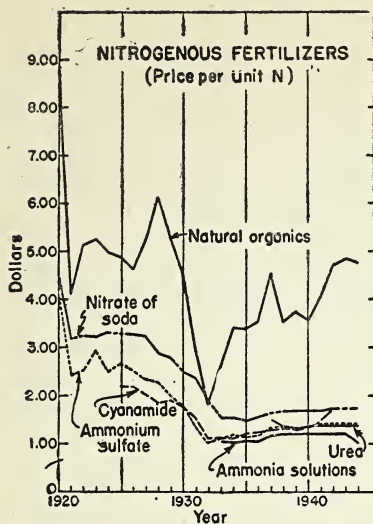
The data indicate very substantial differences in the wholesale price of nitrogen in different materials. The natural organics are very high-priced (an average of \$4.40 per unit for the period 1920 to 1944) but, until the war, provided 10 to 15 percent of the fertilizer nitrogen. Currently the price of chemical nitrogen varies from \$1.75 in sodium nitrate to \$1.42 in ammonium sulfate to about \$1.00 in ammonia solutions. The use of the lower cost forms of nitrogen has increased, and further changes in that direction may be expected.

2. Phosphates

Since 1922 the wholesale price of phosphoric acid in ordinary superphosphate has fluctuated within a range of 43 to 61 cents per unit at Baltimore. The average price for the period 1935 to 1939 was 49 cents. The recent price increase to 64 cents is due largely to higher transportation costs on phosphate rock—rail replacing water shipments from Florida—and higher labor costs.

The wholesale price of phosphoric acid in double superphosphate at Baltimore is about 20 cents per unit higher than in ordinary superphosphate. This differential is reduced to about 10 cents per unit at plants near Tampa, Fla.

The price at which the AAA purchased double superphosphate, f. o. b. point of production, in the period 1937 to 1941 varied from 62.9 to 75.0 cents per unit of available phosphoric acid. During this period purchases were made from the TVA at prices varying from 64.0 to 75.0 cents per unit, from commercial producers in Florida at 62.9 to 65.5 cents, and from industry in Tennessee at 70.7 to 72.0 cents. These prices were substantially higher in most instances than the AAA paid for phosphoric acid in the form of ordinary superphosphate at port plants or even at many interior points of production.



WHOLESALE PRICE OF FERTILIZER MATERIAL

It costs more to produce available phosphoric acid in double superphosphate than in ordinary superphosphate. The higher analysis of double superphosphate makes for lower bagging, handling, and transportation costs, however, so that in some areas the delivered cost of double superphosphate per unit of phosphoric acid is lower than that of ordinary superphosphate. For example, a study of the comparative delivered prices of double superphosphate and ordinary (20-percent) superphosphate, both from commercial sources, under the AAA contracts for 1941, showed average differentials of 1.0 to 9.0 cents per unit in favor of double superphosphate in Illinois, Indiana, Michigan, and Ohio; the differential was 2.0 cents in Kentucky and less than 0.5 cent in Mississippi. In the Atlantic Coast States, on the other hand, the average differential was in favor of ordinary superphosphate; it ranged from 0.15 cent in Vermont and 2.2 cents in Massachusetts to 9.8 cents in Delaware and 15.8 cents in Maryland. Double superphosphate was the cheaper material in limited areas of some of the Atlantic Coast States, but there were substantial areas in Ohio, Kentucky, and Mississippi in which the differential was in favor of ordinary superphosphate.

The average unit value of phosphoric acid in phosphate rock at the mine (Florida) is approximately 9 cents, equivalent to around \$3 per ton. The f. o. b. mine cost of rock is normally about 20 percent of the wholesale price of superphosphate in Baltimore. As indicated in the graph on page 39, the value of phosphate rock at Tennessee and western mines is somewhat higher than at Florida mines. This is due primarily to the differences in the deposits and the resulting higher cost of mining operations in Tennessee and the West.

3. Potash

In the first World War, potash prices were high but dropped to prewar levels with the resumption of imports from Europe. With the rapid development of our domestic industry (chart, p. 62), there was a short drop in potash prices followed by a rise to within about 20 percent of the 1928 to 1932 levels of 67 to 68 cents per unit of potash for muriate of potash and 96 to 97 cents for sulfate of potash.

The indicated prices are f. o. b. ports and are subject to discounts ranging up to 12 percent, depending on programmed deliveries and actual consummation of contracts. Most of the potash moves in the discount periods. The present f. o. b. mine prices of muriate of potash are 8.2 to 11.0 cents per unit lower than the port prices, equivalent to \$5.08 to \$6.82 per ton of 62-percent muriate of potash.

4. Sulfur

Sulfur or its equivalent in pyrites is an important raw material of the fertilizer industry, although sulfur is not one of the commercial plant foods. About 250 and 500 pounds of sulfur are used in the production of 1 ton, respectively, of ordinary superphosphate and of ammonium sulfate. The price of sulfur has ranged from \$12.50 to \$16.96 per ton since 1920, as indicated in the chart on page 39, with rather infrequent price changes.

5. Comparison with Foreign Prices

Fertilizer materials are commodities of international trade. The United States has not had a tariff on them since 1930. Although many factors other than import restrictions enter into the determination of market prices in a country, nevertheless some indication of whether prices are reasonable in the United States is afforded by comparison with prices in other major producing and consuming countries (table 7). The data show that nitrogen prices in the United States were lower in 1935 and 1938 than in any of the other countries except Japan in 1938. The price difference was much smaller, however, in 1938 than in 1935. In the same years phosphoric acid (superphosphate) prices in this country were much lower than in the other countries. In 1935 potash cost less here than in Germany or France, but the position was reversed in 1938. These comparisons indicate that fertilizer prices in the United States are generally lower than in other countries, the greatest difference being in the price of superphosphate.

TABLE 7.—*Prices of plant foods in different countries, 1935 and 1938*¹

Country ²	Nitrogen ³		Phosphoric acid ⁴		Potash ⁵	
	1935	1938	1935	1938	1935	1938
United States.....	\$1.13	\$1.36	\$0.49	\$0.49	\$0.42	\$0.52
United Kingdom.....	1.50	1.59	.77	.83	.....	.....
Germany.....	2.38	1.66	1.05	1.05	.61	.46
France.....	2.44	1.48	1.15	.83	.76	.31
Japan.....	1.38	1.27	.72	.70	.....	.....

¹ Average prices per unit of 20 pounds.

² In view of the controls exercised by several of these countries over currency exchange and trade, these comparisons may need some qualification.

³ As ammonium sulfate.

⁴ As ordinary superphosphate.

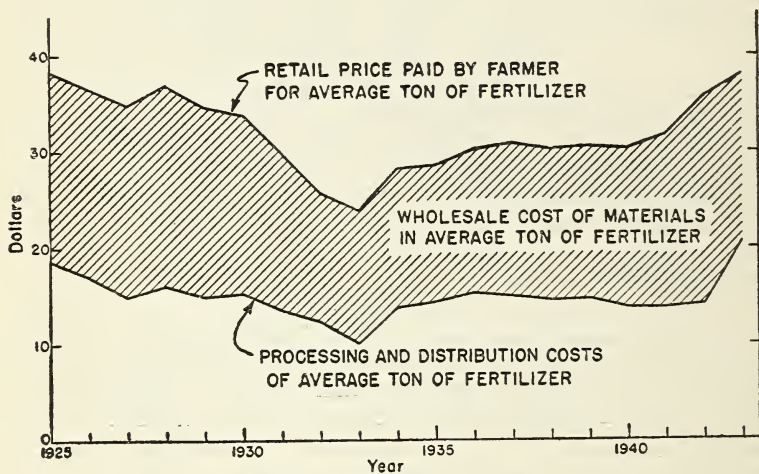
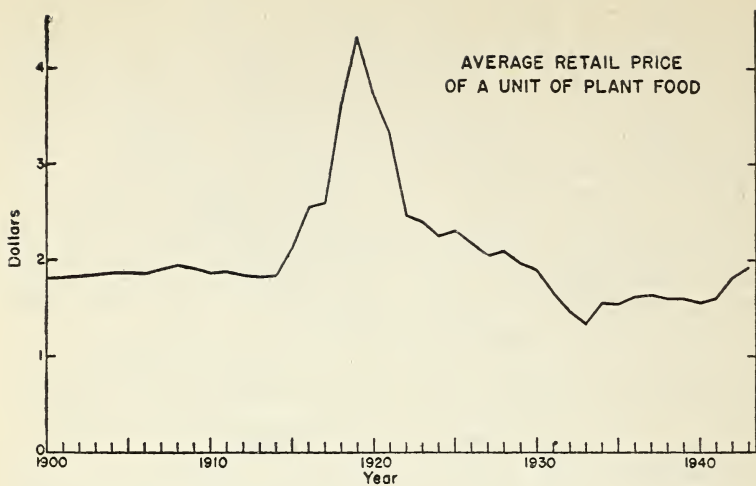
⁵ As potassium chloride.

B. Retail Prices

1. Changes in Prices, 1900 to 1943

The retail price of plant food in mixed fertilizers and separate materials for the period 1900 to 1943 averaged about \$1.85 per unit from 1900 to 1914, increased to \$4.33 in 1919, and then declined continuously to a low of \$1.33 per unit in 1933. (See chart, p. 42.) Since 1934 the price has varied from \$1.55 to \$1.64, with the exception of the war years. The average price in the years 1934 to 1940 was \$1.60 per unit, 24 percent below the 1924 to 1930 price. The indicated price change reflects in large part the previously noted change in the wholesale price of fertilizer materials, particularly the decline in that of nitrogen.

The retail price of fertilizers can be broken down into two factors: First, the wholesale cost of the fertilizer materials; and second, the processing, bagging, and distribution costs. A study of these two costs



**PRICE FLUCTUATIONS
IN THE FERTILIZER INDUSTRY**

per ton of fertilizer for the 1925 to 1943 period indicates that variations in the wholesale price of materials are passed on to the farmer (lower part of graph on p. 42). For example, the wholesale price of materials in the period 1935 to 1939 was \$4.51 per ton lower than in the years 1925 to 1929, and the retail price of the fertilizer was \$5.24 lower. The data also indicate that the processing and distribution costs⁵ have been almost constant since 1926, except in 1932, 1933, and the war years, and amount to almost half the average retail cost, \$14.44 per ton, in the period 1935 to 1941.

2. Plant-Food Content and Retail Price

Increasing the plant-food content of fertilizers, thereby moving more plant food at a given processing and distribution cost, is an effective method of reducing the cost of plant food on the farm. How this has worked for one farmer cooperative in the Northeast is shown in the charts on page 44. The upper chart shows the relative cost of equivalent quantities of plant food in 4-8-8 and 8-16-16 fertilizer for the 1929 to 1942 period, and the cost in 5-10-10 for the 3 years 1940 to 1942. Over most of the period plant food in the higher analysis fertilizer cost the farmer about 20 percent less than in the lower analysis product of the same plant-food ratio. Half this saving was effected by using 5-10-10 in place of 4-8-8.

The lower chart on page 44 illustrates the same points. Equivalent quantities of plant food in 8-16-16 cost only 59 percent as much as in 3-6-6, but most of the saving has been attained by using 5-10-10 in place of 3-6-6. The gradual increase in the plant-food content of fertilizers (see chart, p. 13, and table 12, p. 81) has contributed very materially to a reduction in the retail cost of plant food. Further and more rapid progress is possible if technological advances are more fully utilized.

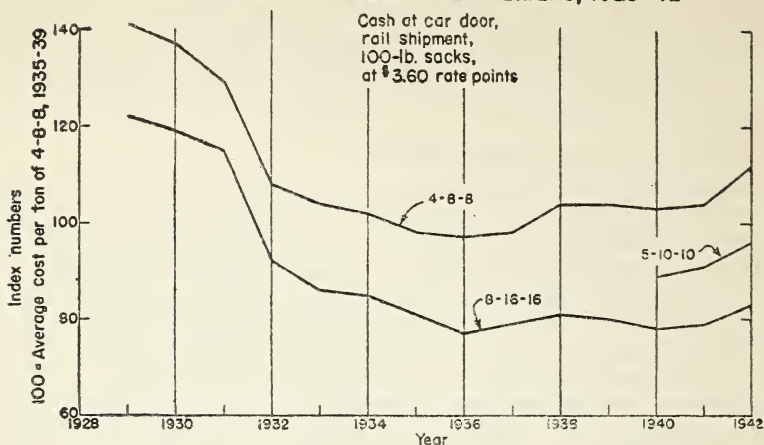
3. Reducing the Farm Cost of Plant Food

There are good possibilities for substantially reducing the delivered-to-the-farm cost of plant food after the war. The following developments are expected or could be brought about by educational work and appropriate action by agricultural leaders. The indicated changes would probably reduce average plant-food costs 15 to 25 percent below 1940 price levels:

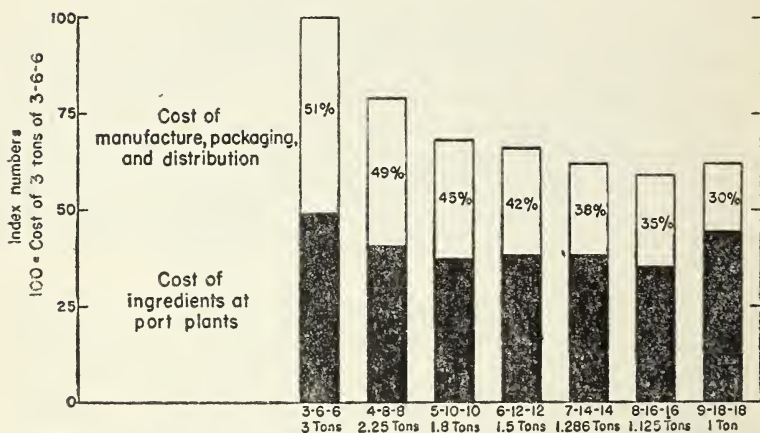
- a. A 20- to 30-percent increase in the average plant-food content of fertilizers.
- b. A 10- to 20-percent reduction in the wholesale price of chemical nitrogen.
- c. A shift in the consumption of nitrogen materials from the more expensive to the lower cost materials; namely, from natural organics to chemical nitrogen and from sodium nitrate to ammonium compounds.
- d. The elimination of unusual wartime costs, as rail transportation of phosphate rock and other materials normally moved by water.
- e. Standardization of grades of fertilizer offered for sale within a State and region, and greater uniformity of fertilizer-control laws, within a region.

⁵ The processing and distribution costs shown in the graph on page 42 include freight on raw materials and finished products from ports to interior plants, and for superphosphate higher production costs than at Baltimore. These figures, therefore, are higher than those that may be calculated from retail-price schedules.

RELATIVE PRICE OF PLANT FOOD IN STANDARD AND HIGH-ANALYSIS COMPLETE FERTILIZERS, 1929-42



RELATIVE FARM COST OF PLANT FOOD IN FERTILIZERS OF DIFFERENT CONCENTRATIONS



INFLUENCE OF CONCENTRATION ON THE CONSUMER COST OF PLANT FOOD IN FERTILIZERS

The first item, increased plant-food content of fertilizers, is the most important. A 25-percent increase in it would reduce delivered-to-the-farm prices about as much as a 20-percent reduction in the wholesale price of chemical nitrogen, phosphoric acid, and potash.

Technically, the suggested plant-food increase is quite feasible, as is indicated by the data of table 8. With the exception of natural organics and phosphates, the average plant-food content of the different classes of materials used in making mixed fertilizers increased more rapidly in the period 1900 to 1941 than the plant-food content of the mixed materials. For example, the plant-food content of chemical nitrogen materials increased by 68.7 percent; phosphates, 35.8; and potash, 120.5; while natural organics decreased by 35.0 percent, in comparison with the increase of 44.6 percent for mixed fertilizers. During the same period the filler and limestone in mixed fertilizers increased by 165.7 percent. The average plant-food content of the materials supplying nitrogen, phosphoric acid, and potash, therefore, increased by about 64 percent. It may be expected that the use of higher analysis materials will continue to increase, for they have been shown to be excellent sources of plant food and are usually the low-cost sources.

The newer and low-cost nitrogen materials, for example, contain from 30 to 45 percent nitrogen. Most of the potash is from muriate containing 60 percent or more K_2O , again the lowest cost source. The production of higher analysis phosphates is increasing. The elimination of some of the dolomite currently used in fertilizers may be expected to result from a more adequate liming program and thus make possible higher analysis fertilizers. As previously indicated, the rapidity of adoption of such desirable changes will depend on an adequate educational program and appropriate action by agricultural leaders and the fertilizer industry.

TABLE 8.—*Plant-food content of different classes of materials used in the manufacture of mixed fertilizers and the percentages of limestone and filler in mixed fertilizers, in certain years*

PLANT-FOOD CONTENT					
Class of material	1900	1909	1919	1929	1941
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Chemical nitrogen....	16.6	17.6	17.5	20.3	28.0
Natural organics....	11.7	10.8	10.4	10.5	7.6
Phosphates.....	14.8	15.8	16.3	18.9	20.1
Potash.....	24.4	23.6	23.2	32.6	53.8
Mixed fertilizer.....	13.9	14.8	13.9	17.5	20.1
LIMESTONE AND FILLER IN MIXED FERTILIZERS					
Limestone.....	0.1	0.1	0.2	2.1	6.6
Filler.....	6.6	8.0	12.1	10.7	11.2
Total.....	6.7	8.1	12.3	12.8	17.8

FERTILIZERS AND LIME RESOURCES

A. Nitrogen

Soil, coal, and air contain the Nation's nitrogen resources. The total supply of nitrogen in the surface 6 inches of our soils is about 1.5 billion tons, about 350 million tons of which are contained in the cropped soils. Usually, the subsoils are relatively low in nitrogen. The United States has no important deposits of mineral nitrates comparable with those found in Chile.

Nearly all the ammonium sulfate used as fertilizer in this country is obtained by processing coal in byproduct coke ovens. In modern plants the yield corresponds to 22 pounds of nitrogen per ton of coal treated. As the Nation has very large reserves of coking coal, the supply of byproduct nitrogen will continue to be conditioned only by the demand for coke.

The air over each acre of the world's surface contains nearly 35,000 tons of nitrogen. The development of processes for the fixation of this nitrogen assures a supply for domestic agriculture limited only by the facilities available for its recovery.

B. Phosphates

The important primary sources of phosphate for agriculture are the soil, iron ores, and phosphate rock. The content of phosphoric acid in the soils of the United States is about the same as that of nitrogen, namely, 1.5 billion tons in all the surface soils, or 350 million in those of cropped land. Unlike nitrogen, however, the soil supply of phosphorus is not increased by rainfall or the action of soil organisms; when depleted it can be augmented only by the application of phosphate fertilizers. The subsoil usually contains about as much phosphorus as the surface soil, so that erosion losses are not so serious in this respect as in the case of nitrogen.

Phosphatic slags obtained as byproducts of the smelting of high-phosphorus iron ores are important sources of phosphorus for European agriculture. Because of the low content of phosphorus in most of the iron ore currently used in this country, the domestic production of such slags is very limited. The United States has a considerable reserve of high-phosphorus ore, however, and this will come into increasing use as the supply of low-phosphorus material is exhausted.

Phosphate rock deposits are widely distributed throughout the world. The total known reserve is estimated at approximately 28.87 billion tons, containing in the neighborhood of 7 billion tons of P_2O_5 . (See below.) The supply of phosphate rock in the United States is estimated at 14.886 billion tons, or 51.5 percent of the total world supply. The rest is principally in the Soviet Union and North Africa.

Supplies have been developed in Egypt and certain of the Pacific Islands, notably Nauru and Ocean Island, and deposits—in many cases largely or totally undeveloped—occur in a number of other countries, chiefly Brazil, Canada, China, Mexico, Palestine, and Poland.

World reserves of phosphate rock:

	<i>1,000 tons</i>
United States	14,885,763
Florida	5,691,660
Tennessee	217,804
Idaho, Montana, Utah, and Wyoming	8,943,079
Arkansas, Kentucky, and South Carolina	33,220
U. S. S. R. (Russia)	8,342,291
North Africa (Algeria, Morocco, Tunisia)	3,876,277
Egypt	197,314
Nauru and Ocean Island	154,324
Other countries	1,414,287
Total	28,870,256

The reserve of phosphate rock in the United States is distributed (by percentage) as follows: Florida, 38.2; Tennessee, 1.5; Western States (Idaho, Montana, Utah, and Wyoming), 60.1; and other States (Arkansas, Kentucky, and South Carolina), 0.2. The location of our major deposits is shown in the map on page 58. In addition to the Nation's estimated reserve of 14,886 billion tons of phosphate rock, there are extensive areas of known and probable deposits that have not been evaluated, principally in the West. Thus, our total reserve is doubtless considerably larger than the foregoing figures indicate.

C. Potash

The potash resources of the United States are contained chiefly in the soil, in brines, and in deposits of water-soluble minerals and silicate rocks. The soils of this country are far richer in potash than in nitrogen or phosphoric acid. The surface 6 inches of our cropland contains approximately 5 billion tons, or as much as the total known world reserve of water-soluble potash. Succeeding layers of soils usually contain even higher proportions, so that erosion will not deplete this important source of potash reserves.

In the central and western parts of the country native-soil potash usually becomes available to plants at a rate sufficient to support maximum crop growth. The soils of the Midwest and North furnish sufficient available potash for continued growth, but additions of potash fertilizers are generally required to attain maximum yields. Even in the South, which contains the most highly weathered and depleted soils in the country, many of the important agricultural soils are capable of furnishing a substantial part of the potash requirements of plants. Our extensive soil resources, therefore, supply important quantities of potash, but in many areas the rate of availability is such that potash fertilizers must be used to obtain efficient and economical crop production.

Very large deposits of such potash-bearing silicate rocks as feldspar, shales, greensand, and leucite are widely distributed in the United States, but despite numerous attempts no economical processes for extracting the potash have yet been developed.

Nearly all the potash fertilizer used in this country is obtained from brines and water-soluble minerals. Our total known reserve of potash in these forms is estimated at approximately 90 million tons, chiefly in deposits in the Carlsbad, N. Mex., area. It is estimated that the total reserve of water-soluble potash in foreign countries amounts to 4,980 million tons distributed as follows: Germany, 2,500; Palestine, 1,200; the Soviet Union, 700; France, 300; Spain, 270; and Poland, 10.

The Carlsbad deposits occur in the so-called Permian Basin, which extends from Kansas to southern Texas and laterally into Colorado and New Mexico. While some 40,000 square miles in the southern part of the basin are tentatively considered as potash territory, intensive test drilling has been done only in an area of about 120 square miles near Carlsbad. Very meager exploratory work in a 3,000-square-mile area has shown the presence of soluble potash salts, but available information is insufficient to make any estimates of reserves in other than the 120-square-mile area. Furthermore, drilling operations have indicated the probability that extensive subterranean deposits of potash exist in Utah. Thus, there is good foundation for the belief that careful investigation of the known and probable potash-bearing areas will greatly enlarge our usable reserve of water-soluble potash.

D. Sulfur

Our large requirement of sulfur, in the form of sulfuric acid, for the manufacture of ammonium sulfate and superphosphates has been pointed out in a preceding section. In the decreasing order of production the principal domestic sources of sulfur are brimstone, pyrites, and smelter gases and fumes, of which the first is by far the most important. Fertilizers are made with sulfuric acid manufactured from all these sources.

The total 1944 marketed production of sulfur in the form of brimstone is estimated at approximately 4 million tons, comprising 2.2 million tons for use in manufacture of sulfuric acid and 1.8 million tons for export and for nonacid uses. In the 5 years preceding 1941 the annual exports and imports of elemental sulfur (crude and refined) averaged 732,245 and 10,255 tons, respectively. The 1944 production of sulfur in the form of pyrites was in the neighborhood of 500,000 tons.

Data on the Nation's reserves of sulfur sources are meager. Except for brimstone, little or no information appears to be available. Concerning the reserve of brimstone, the Bureau of Mines stated in 1930—The Texas deposits probably contain in excess of 40,000,000 tons of sulphur without allowance for recent discoveries. Many other occurrences in the United States are not included in these estimates, such as those of Culberson County, Tex., where an immense tonnage is reported to exist. Some of them probably have commercial possibilities.

As the foregoing figure does not take into consideration the Grand Ecaille Dome that came into large-scale production in Louisiana a few years ago, the reserve of exploitable brimstone undoubtedly is greatly in excess of 40 million tons. In view of the importance of sulfur to the fertilizer and other industries, however, it is desirable to have more complete information on the reserves of brimstone, pyrites, and other raw materials for sulfuric acid manufacture.

E. Liming Materials

The Nation's resources of liming materials are widely distributed in nearly all the States. Although they comprise chiefly deposits of high calcium and magnesium limestones, deposits of marble, marl, shells, and chalk are important additional sources in many localities. Much agricultural limestone is obtained in the concentration of metallic ores, especially lead and zinc, and in the preparation of aggregates for road building.

Certain industrial processes yield byproduct or waste liming materials that are valuable for agricultural purposes. These include slags from iron blast furnaces, phosphate smelting furnaces, and other high-temperature operations, as well as spent lime from paper mills, tanneries, sugar mills, acetylene plants, and others.

FOREIGN TRADE

Fertilizers have constituted an important item in our foreign trade; exports averaged \$17,720,000 in the period from 1936 to 1940, while imports averaged \$36,192,000. There have been no tariffs or import restrictions on fertilizers since 1930, and Federal laws prohibit the participation of American companies in world cartels. These policies have undoubtedly done much to provide the American farmer with an abundant supply of fertilizers at prices generally lower than in any other country.

A. Nitrogen

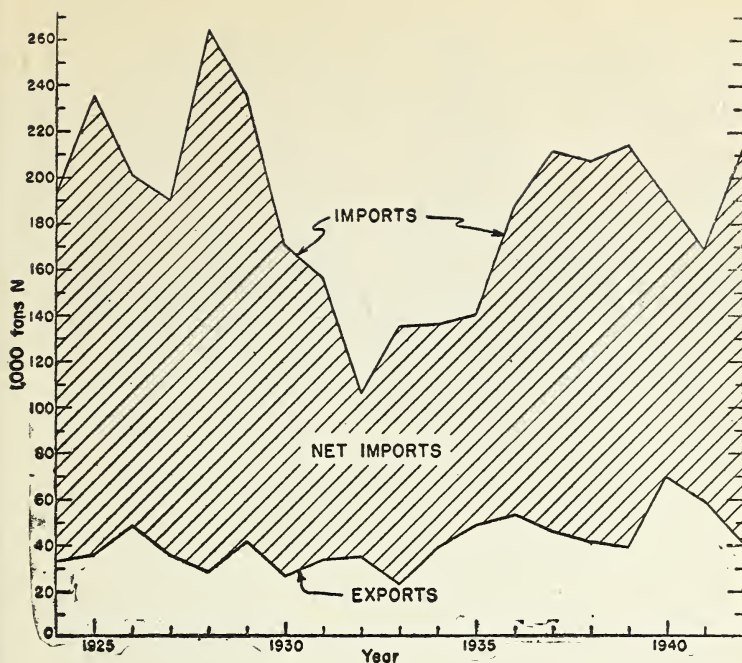
Total imports, exports, and net imports of nitrogen fertilizers are given in the charts on page 51. The United States is the only major nitrogen-producing and -consuming country that has had a large excess of imports over exports. In 1929, 1934, and 1938 net imports were 55, 36, and 44 percent, respectively, of total fertilizer nitrogen consumption. Our principal imports were sodium nitrate, cyanamide, and ammonium sulfate from Chile, Canada, and Europe, respectively. Sodium nitrate and ammonium sulfate were our principal exports.

As a result of the construction of war plants, the United States now has plant capacity to make considerably more nitrogen fertilizers than will probably be used even under conditions of full employment. Similar action was taken in Canada, and during the war that country exported large quantities of nitrogen fertilizer to the United States. Imports from Chile have been maintained at a high level. Both Canada and Chile will want to retain this market, although the United States could easily be self-sufficient. At the same time it must be recognized that a strong domestic nitrogen industry is an essential part of national defense.

B. Phosphates

Our foreign trade in phosphatic materials is shown in the charts on page 52. Exports of phosphate rock were large, an average of 1,222,000 tons per year during the period of 1935 to 1939. Most of this went to Europe and Japan, neither of which has good deposits of phosphate. Exports of other phosphatic materials were small, as were imports.

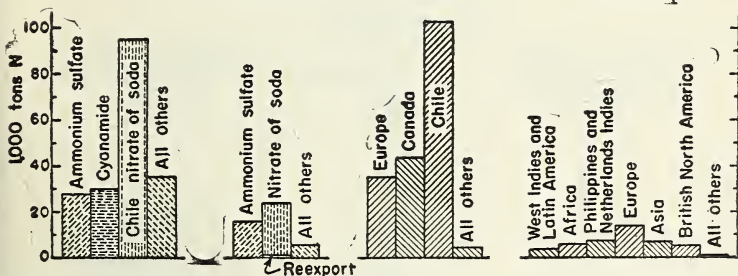
In view of the fact the United States has about half of the world's known phosphate resources, continued exports of this important natural resource may be anticipated. It may be expected, however, that Europe will obtain more phosphate from North Africa and the Soviet Union in order to save dollar exchange for other American products. Our exports of phosphate, therefore, may decline.



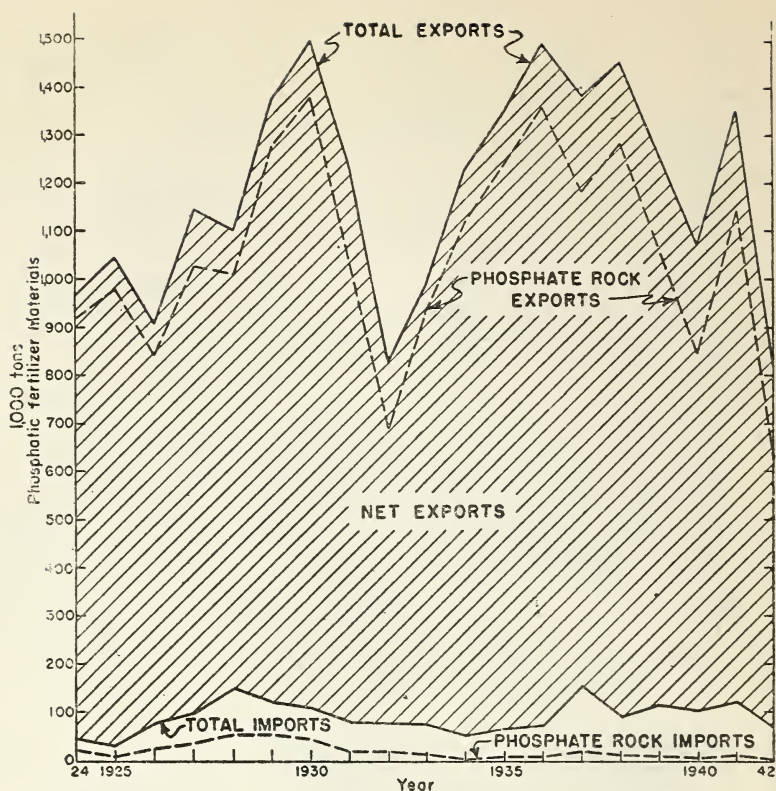
AVERAGE IMPORTS
BY COMMODITIES
1935-39

AVERAGE IMPORTS
BY COUNTRIES
1935-39

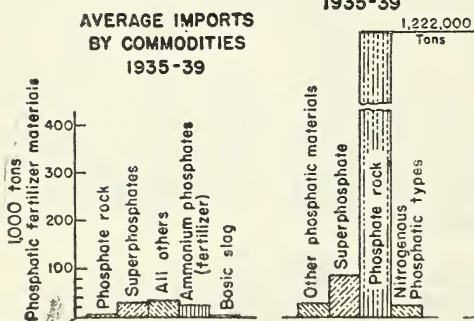
AVERAGE EXPORTS
BY COUNTRIES
1935-39



UNITED STATES TRADE IN NITROGENOUS CHEMICAL FERTILIZERS, 1924-42

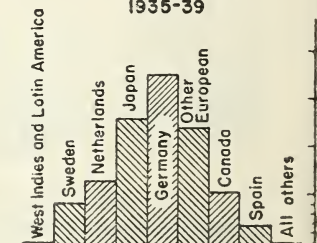


AVERAGE EXPORTS BY COMMODITIES 1935-39



AVERAGE IMPORTS BY COMMODITIES 1935-39

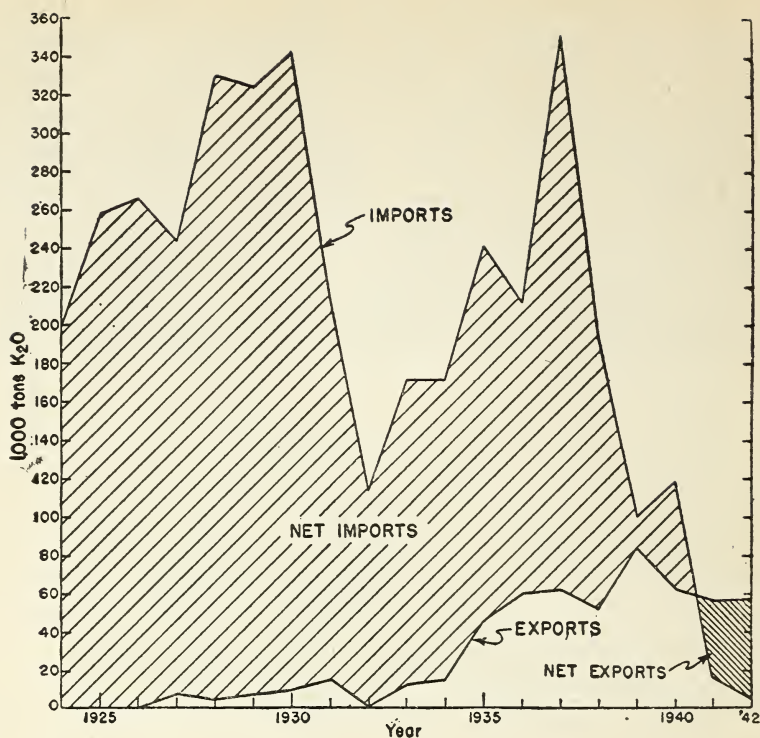
AVERAGE EXPORTS OF PHOSPHATE ROCK BY COUNTRIES 1935-39



UNITED STATES TRADE IN PHOSPHATE ROCK AND PHOSPHATIC FERTILIZERS, 1924-42

C. Potash

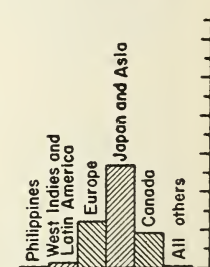
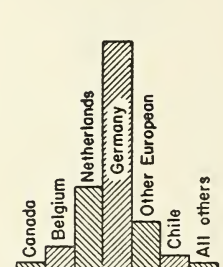
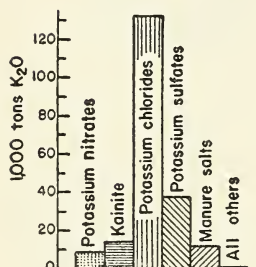
Prior to 1940 the United States was a large importer of potash. Foreign trade in potash fertilizer materials, however, fluctuated considerably in the period 1930 to 1940. The trends are charted on page 54. The decline in imports in 1930 to 1932 undoubtedly was due to the depression and to increased domestic production, while that beginning in 1937 resulted from a further expansion of the domestic industry which was in progress at the time war broke out in Europe. The first exportation in recent years occurred in 1927, but exports remained quite small until 1934 and 1935. They continued to expand until the beginning of World War II. At that time imports practically ceased and the potash industry voluntarily stopped all exports except to friendly nations. The domestic industry not only met increased domestic requirements but supplied very substantial quantities to our allies.



AVERAGE IMPORTS
BY COMMODITIES
1935-39

AVERAGE IMPORTS
BY COUNTRIES
1935-39

AVERAGE EXPORTS
BY COUNTRIES
1935-39



UNITED STATES TRADE IN POTASSIC FERTILIZERS, 1924-42

PLANT LOCATIONS AND PRODUCTION CAPACITY

The location and the production capacity of plants are important considerations in determining our ability to meet demands for fertilizers. Plant locations are shown on three maps (pp. 56, 58, and 62). Although it is more difficult to obtain detailed information on production, reliance can be placed on data of the War Production Board, both on production and on plant capacity.

The consumption of nitrogen for most industrial purposes is continuous throughout the year. On the other hand, the demand for agricultural use, insofar as the consumer—the farmer—is concerned, normally is markedly seasonal and is confined principally to the spring months. To meet this situation, as well as to make efficient use of plant capacity and to maintain low operating and production costs, the manufacturer of fertilizer nitrogen may provide large-scale storage facilities or else induce the fertilizer distributors and mixers to take a large proportion of their requirements during off-season periods. The latter is the preferable expedient and is accomplished by price reductions on deliveries at those times. The same problem confronts the producers of phosphate and potash materials and, to an even greater extent, the manufacturers of mixed fertilizers.

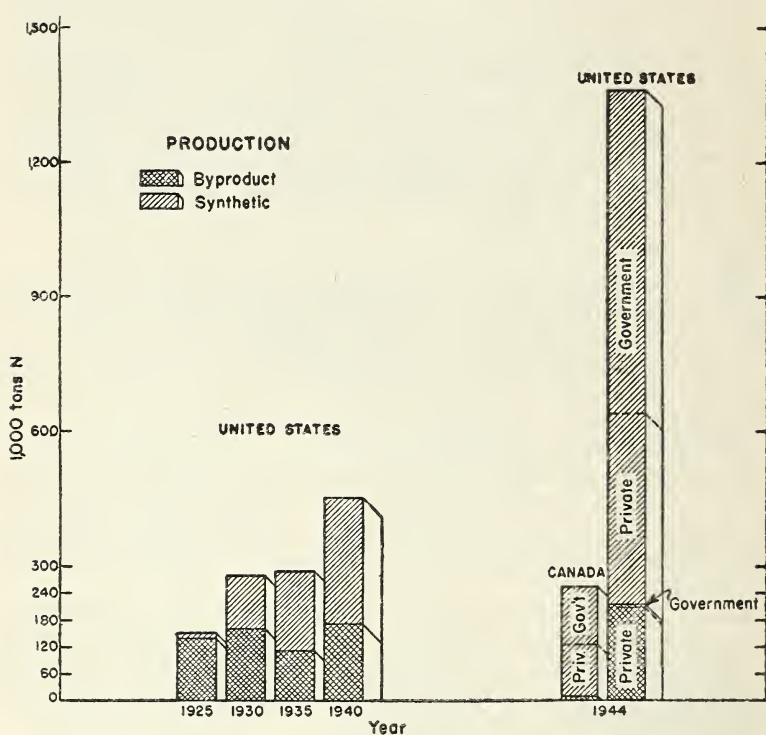
A. Nitrogen

Aside from natural organic materials, our nitrogen production falls in two classes—byproduct and synthetic—known together as chemical nitrogen. There are 114 chemical nitrogen plants in the United States, of which 95 produce byproduct nitrogen and 19 synthesize nitrogen compounds from the air. The geographical distribution of these plants is shown in the map on page 56.

The byproduct nitrogen plants are chiefly in heavily industrialized areas, mostly in the eastern part of the country. Thus 87 of the 95 plants are east of the Mississippi River. Production of byproduct nitrogen in the heavy nitrogen-fertilizer-consuming States of the South and Southeast is confined largely to 6 plants located in the Birmingham, Ala., district.

Ten of the 19 synthetic nitrogen plants, comprising 68 percent of their total capacity, are located east of the Mississippi River. Three are in California, two each in Louisiana, Michigan, New York, and West Virginia, and one each in Alabama, Arkansas, Kansas, Kentucky, Missouri, Ohio, Texas, and Virginia.

Until 1940 the domestic chemical nitrogen industry was entirely a private enterprise, and the production of byproduct nitrogen is still almost completely in the hands of private interests. With respect to synthetic nitrogen, however, the Government now owns 10 plants, erected to insure an adequate supply for military purposes, which have



**PRODUCTION OF CHEMICAL NITROGEN
AND
LOCATION OF PLANTS IN NORTH AMERICA**

64 percent of the total synthetic nitrogen capacity. The privately owned plants are operated by 7 companies.

There are six synthetic nitrogen plants in Canada, owned in equal number by private industry and by the Canadian Government. Recently they have supplied considerable fertilizer nitrogen to the United States and they will undoubtedly be in position to supply an even greater quantity in the postwar period.

The domestic production of chemical nitrogen in certain years of the period 1925 to 1944 is shown by the chart on page 56. The production in 1944 is estimated to have been 1,364,000 tons, of which synthetic nitrogen amounted to 1,149,000 tons, or 84 percent.

As the manufacture of byproduct nitrogen is geared to the coke industry, its production is limited principally by the demand for iron and steel. Production of synthetic nitrogen, on the other hand, is conditioned only by the market demand for nitrogen compounds. The output of byproduct nitrogen goes mostly for fertilizer use, while, aside from military uses, the greater part of the synthetic nitrogen production has been used for industrial purposes—approximately 328,000 tons in the year ended June 30, 1944. It is evident, therefore, that chemical nitrogen is indispensable to our agricultural welfare and to our industrial economy, as well as to national defense.

During the last 20 years the Nation's capacity to produce chemical nitrogen has grown from 162,800 to 1,510,100 tons. (See table 9.) There has been a rather gradual increase in the production of byproduct nitrogen—from 147,500 tons in 1925 to 225,000 in 1944. Synthetic nitrogen production, on the other hand, has increased tremendously—from 15,300 tons in 1925 to 1,285,100 in 1944. Government plants alone in 1944 had an 854,000-ton capacity. In most of the prewar years the production of chemical nitrogen did not exceed 75 percent of capacity, and in some years it was less than 50 percent. Furthermore, at least some of the synthetic nitrogen plants are capable of producing more than their rated capacities.

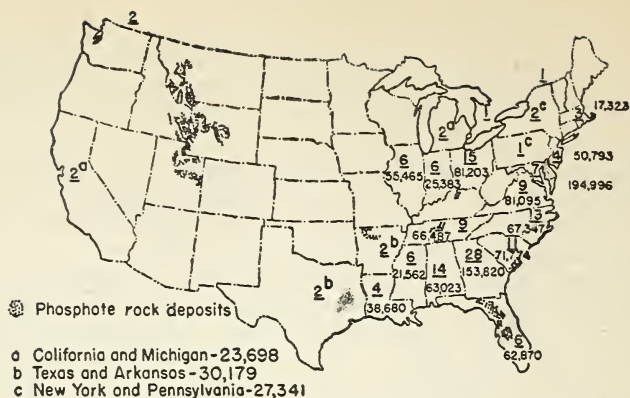
TABLE 9.—*United States capacity for production of chemical nitrogen*

Year	Byproduct	Synthetic	Total
	<i>Tons N</i>	<i>Tons N</i>	<i>Tons N</i>
1925.....	147,500	15,300	162,800
1930.....	194,500	195,500	390,000
1935.....	185,000	341,350	526,350
1940.....	185,000	380,300	565,300
1944.....	225,000	¹ 1,285,100	1,510,100

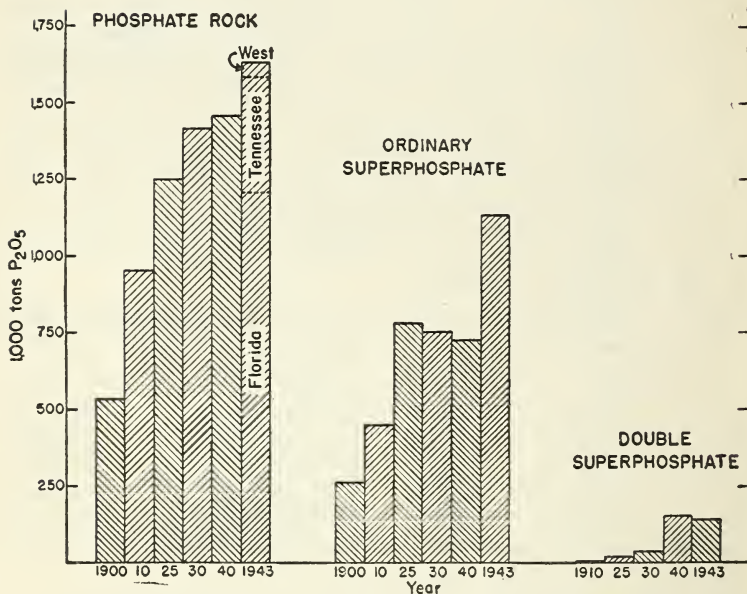
¹ 431,100 tons in private plants; 854,000 tons in Government plants.

B. Phosphates

The location of the principal domestic deposits of phosphate rock and the total production therefrom in certain years of the period 1900 to 1943 are discussed on pages 46 and 47 and are shown on the map on page 58. Production data for the years 1920 to 1944 are given in more



PRODUCTION OF ORDINARY SUPERPHOSPHATE (TONS P_2O_5) AND NUMBER OF PLANTS BY STATES, 1943.



PRODUCTION OF PHOSPHATIC FERTILIZER MATERIALS

detail in table 21 (p. 90). The production normally is governed by the export demand as well as by the domestic requirement.

The 1943 output of phosphate rock was produced by 27 companies, of which 14 operated in Florida, 8 (including the TVA) in Tennessee, 1 in both Florida and Tennessee, 1 in Virginia, and 3 in the West.

Even during the war there was no shortage in the total domestic supply of phosphate rock. Although the Tennessee output during the last 3 years has been somewhat less than could have been used, the deficit has been met by shipments from Florida. Owing to the character of the deposits, the production from Florida can probably be expanded rapidly enough to meet any foreseeable demand. Further expansion of production from the limited deposits in Tennessee would seem inadvisable. A large increase in the use of western rock would require the opening of new mines, which cannot be done so easily as in either Florida or Tennessee. Nevertheless, the western deposits constitute our largest reserve of phosphate rock, and their utilization should be increased to the extent that this is economically feasible.

Nearly all the domestic production of available P_2O_5 for fertilizer use is in the form of ordinary superphosphate and double superphosphate. In 1943 ordinary superphosphate was produced by 152 plants operated by 57 companies, the geographical distribution of which is shown in the map on page 58. Now 161 ordinary superphosphate plants are operated by 65 companies.

There are 10 plants for the manufacture of double superphosphate. These are operated by 10 companies, including the TVA. Four of them (2 currently are not producing double superphosphate) manufacture the material with phosphoric acid made from elemental phosphorus; the others produce it with phosphoric acid made by treating phosphate rock with sulfuric acid. Both double and ordinary superphosphates are produced at 7 of the plants.

As would be expected, the regional distribution of the ordinary superphosphate plants is roughly proportional to the regional consumption of phosphate fertilizer. Thus, 10 percent of the plants are in the Middle Atlantic States, 68 percent in the South, and 19 percent in the Middle West. More than 90 percent of the plants are east of the Mississippi River.

Of the double superphosphate plants, three are in Tennessee, two in Florida, and one each in Alabama, Montana, New Jersey, South Carolina, and Texas. With three exceptions the plants are located at or near phosphate rock deposits. Proximity to sources of acid and electric power, as well as to supplies of phosphate rock, is an important consideration in the location of double superphosphate plants.

Concentrated phosphates, principally ammonium phosphate, produced at Trail, British Columbia, are an important factor in the supply of fertilizer for the Western States and the Hawaiian Islands. It appears certain that in the postwar years even larger quantities of phosphate will be furnished to the United States from this source. At present

there is no domestic production of ammonium phosphate for fertilizer, though it was formerly manufactured, chiefly for export.

The production of ordinary and double superphosphates in certain years of the period 1900 to 1943 is shown in the chart on page 58. Production of ordinary superphosphate increased from 597,200 tons of P_2O_5 in 1938 to 1,213,100 tons in 1944 (table 22, p. 90). Production of double superphosphate reached a maximum of 151,400 tons of P_2O_5 in 1940 but owing to the war decreased to 126,500 tons in 1944.

The estimated capacity for the production of ordinary superphosphate increased from 335,000 tons P_2O_5 in 1900 to 2,067,500 tons in 1945. In the same period, double superphosphate capacity increased from 1,000 to 287,000 tons. This makes a total increase of 2,018,500 tons of P_2O_5 , or 600.7 percent, for the 46-year period (table 10).

TABLE 10.—*Estimated capacity for production of superphosphate in the United States*

Year	Ordinary superphosphate	Double superphosphate	Total
	<i>Tons P_2O_5</i>	<i>Tons P_2O_5</i>	<i>Tons P_2O_5</i>
1900.....	335,000	1,000	336,000
1910.....	940,000	3,000	943,000
1920.....	1,440,000	7,000	1,447,000
1930.....	1,600,000	44,000	1,644,000
1940.....	1,528,000	180,000	1,708,000
1945 ¹	² 2,067,500	287,000	2,354,500

¹ Including facilities under construction as of December 31, 1944.

² Not strictly comparable with preceding years, since the increase over 1940 results in part from new facilities and in part from better estimates of the operating capacities of individual plants as revealed by a recent survey by the War Production Board.

The annual production of ordinary superphosphate has seldom exceeded 75 percent of the estimated production capacity, and in many years it has been less than 50 percent. The production in 1944 was 59 percent of the capacity of all plants, including those under construction. In contrast to ordinary superphosphate, the production of double superphosphate has ranged from 80 to 95 percent of capacity in many years, except during the depression and subsequent to 1941.

Farmer cooperatives operate three ordinary superphosphate plants. These plants (in Georgia, Indiana, and Maryland) have an estimated total capacity of about 20,000 tons of P_2O_5 annually.

The present capacity for double superphosphate includes 123,750 tons of P_2O_5 estimated for the TVA plant at Wilson Dam, Ala., based on the conversion into double superphosphate of the total TVA capacity for production of electric-furnace phosphorus. It also includes the prewar capacity of two private plants for converting elemental phosphorus into double superphosphate, which is soon expected to be available again for this purpose.

More than 90 percent of the total capacity for superphosphate production is east of the Mississippi River. About 55 percent of the total is in the Southern and 25 percent in the Middle Atlantic States.

Prior to 1941 the Nation's capacity for sulfuric acid production was more than ample to meet all the requirements of the superphosphate industry. After that, however, the great expansion in the manufacture of explosives and other war materials resulted in shortages of acid for superphosphate manufacture, even though the capacity for acid production had been greatly increased. In the postwar period the supply of acid undoubtedly will again be sufficient to meet all demands.

The greater part of the wartime increase in capacity for sulfuric acid production was effected with Government funds. The Government-owned plants, though widely distributed throughout the country, were concentrated to a considerable extent in the Middle West—a region in which the consumption of phosphate fertilizers is expected to undergo marked expansion in the postwar period. Careful consideration should be given, therefore, to the advisability of the postwar utilization of at least some of the Government plants in this and other regions to manufacture acid for fertilizer production.

C. Potash

The domestic output of potash is almost all in the form of water-soluble salts produced at five plants, operated by as many companies. Three of these are in New Mexico and one each in California and Utah. (See map, p. 62.) The New Mexico plants operate on mineral deposits and the others on brines. About 85 percent of the 1943 production (739,000 tons of K_2O) was from the deposits in the Carlsbad, N. Mex. area. The total production was mostly from deposits and brines on Government and patented lands.

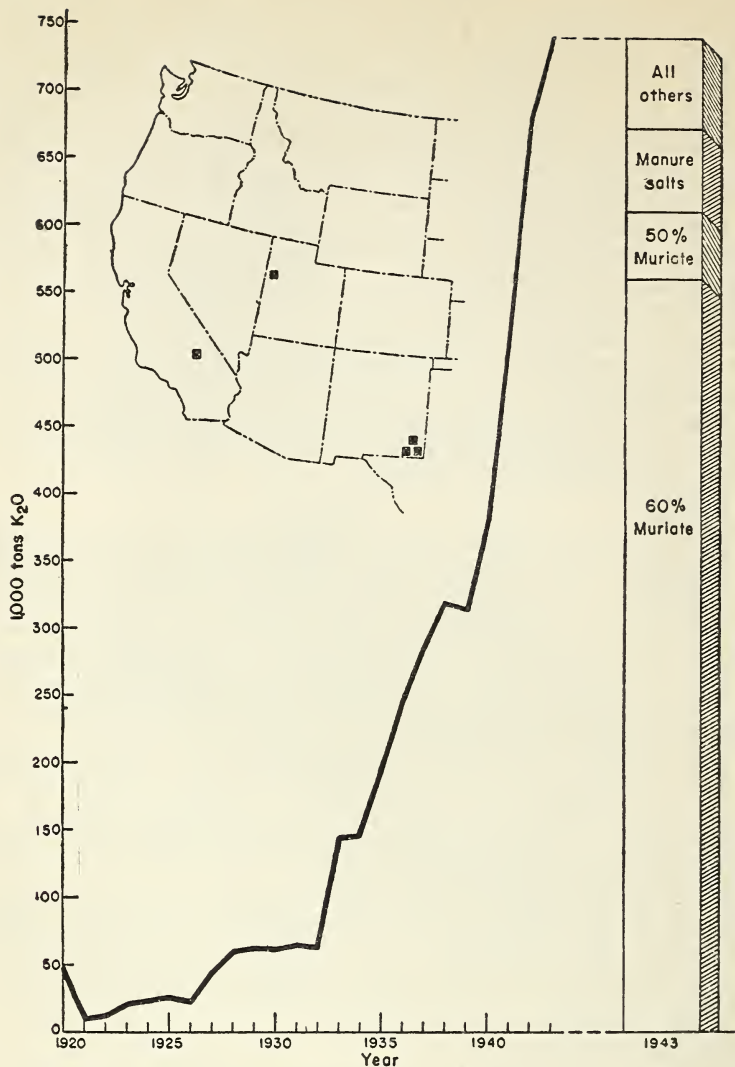
The capacity for potash production gradually increased from 540,000 tons of K_2O in 1940 to 800,000 in 1944. In terms of the estimated capacities in the respective years, the production of potash increased from about 70 percent in 1940 to 90 percent in 1941 and to nearly 100 percent in subsequent years.

As with other fertilizers, the farmer demand for potash is highly seasonal. Therefore, the movement of potash to fertilizer distributors and mixers during off-season periods is encouraged by granting price discounts on orders placed in advance for approximately equal monthly deliveries in summer, fall, and winter.

D. Mixed Fertilizers

The number of plants manufacturing mixed fertilizers varies from year to year, but the present total is estimated at about 1,000, operated by some 800 companies and individuals. Regional distribution of the plants is closely correlated with regional consumption of fertilizer.

In the fiscal year 1943 the production of mixed fertilizers amounted to 7.6 million tons, averaging about 21 percent of plant food. About 80 percent of the output was in the form of mixtures containing all



**PRODUCTION OF POTASH
AND
LOCATION OF MAJOR PLANTS**

three of the plant-food elements: nitrogen, phosphorus, and potassium.

The highly seasonal demand by farmers for fertilizer creates problems of storage, labor, and transportation that are even more difficult in relation to the production and movement of mixed fertilizers than of fertilizer materials. The distribution of mixed-fertilizer production among many plants widely scattered throughout the consuming areas is a very important factor in the solution of these problems.

E. Liming Materials

The total number of plants that produce agricultural liming materials is unknown, but certainly it is very large. In addition to the commercial operators, which number at least 1,000, numerous small operators, both individuals and cooperative groups, produce liming materials for their own use only. Considerable agricultural limestone is also obtained as a byproduct of the preparation of aggregates for road building. Local sources of liming materials occur in nearly all sections of the country and, in general, the industry is distributed correspondingly.

Data on the capacity to produce agricultural liming materials are not available. With the present limitations on labor, however, the current production capacity, at least for most of the materials, is probably not greatly different from the current consumption (about 18,750,000 tons in 1943). Under normal conditions there will be little or no difficulty in rapidly expanding the production in most if not all sections of the country to meet all demands.

F. Farmer Cooperatives

Farmer cooperatives are playing an increasingly important role in the manufacture and distribution of fertilizers. More than 40 plants, widely distributed throughout the country, are now operated by at least 25 cooperatives. In addition, some 1,000 cooperative groups distribute or purchase fertilizers for their members.

It is estimated that farmer cooperatives handled approximately 8.1 percent of the fertilizer (11,305,945 tons) that was distributed in the continental United States in the year ended June 30, 1943. Regionally, the proportion distributed by cooperatives ranged from about 5.0 percent in the South Central to 14.7 percent in the New England and Middle Atlantic States. About 72.1 percent of the materials distributed by cooperatives was in the form of mixtures, in comparison with 67.2 percent for the combined distribution of cooperatives, governmental agencies, and the commercial industry. Inasmuch as governmental distribution consisted largely of separate materials, it is probable that the ratio of mixed fertilizers to separate materials distributed by cooperatives was about the same as for commercial industry. Also, the average plant-food ratio and percentage of plant food in the total quantity of mixed fertilizers distributed by cooperatives were not greatly different from the averages for other commercially distributed mixtures.

RESEARCH

Research has played an increasingly important role in the production and use of fertilizers. The considerable decrease in the cost of fertilizers to the American farmer in the past 50 years has resulted largely from chemical and technological researches that have led to the improvement of existing methods and to the development of new processes for the production of nitrogen, potash, and phosphate materials and mixtures. Equal if not larger savings to the farmer have been effected by studies of (1) the fertilizer requirements of soils and crops under the widely diverse conditions of the country's agricultural areas and farming systems, (2) the materials and mixtures best adapted to meet these requirements, and (3) the chemical, physical, and biological relationships of fertilizers, soils, plants, and animals. Research in these general fields of fertilizer production and use are legitimate functions of the Government.

A. Governmental Participation in Relation to Private Industry

For many years government agencies, both State and Federal, have actively participated in all phases of fertilizer research. The passage in 1887 of the Hatch Act, providing for the establishment of State agricultural experiment stations with Federal support, placed the agronomic phases of fertilizer research on a permanent basis, with the result that responsibility for progress in this work has devolved largely on government officials. Though this type of research has been done principally by government organizations, there has been strong support and participation by industry, particularly in the form of fellowships at universities and colleges.

In 1911 the importance of chemical and technological research on fertilizers and fertilizer materials was recognized by Congress, when it appropriated funds for such work in the Department of Agriculture. The annual appropriations have continued to the present. World War I caused an increase in Federal research on fertilizer technology, chiefly potash and fixation of atmospheric nitrogen, an outgrowth of which was the establishment of the Fixed Nitrogen Research Laboratory—later merged with other fertilizer technology work of the Department of Agriculture. The Tennessee Valley Authority, since its establishment in 1933, has engaged in fertilizer research work, largely in respect to pilot-plant and full-scale operations for the production of phosphate and, more recently, nitrogen compounds. The fertilizer research activities of the Department of the Interior have related principally to work on the concentration of potash and phosphate ores.

In general, it is the policy of Federal agencies to make the results of their chemical and technological researches on fertilizers freely avail-

able to private industry and to encourage industry to put these results into practice to the extent that they prove to be technically and economically feasible. The commercial adaptation of the research findings has been greatly facilitated by the employment by industry of persons who have acquired specialized knowledge of the subject as a result of their work in government agencies. Industry has cooperated with government by supplying technical data and information gained in many years of process research and manufacturing experience.

B. Fertilizer Technology

The advances in fertilizer technology have been many and varied during the past 35 years. These advances have resulted in the production of more efficient and more economical fertilizers. They have freed the Nation from dependence on foreign sources of supply. At the same time, they have made possible the maintenance of fertilizer prices that are low in relation to the costs of the other principal commodities purchased by farmers.

1. Nitrogen

Until after the first World War, byproduct nitrogen compounds (coke-oven ammonia and low-analysis organic ammoniates) and sodium nitrate imported from Chile furnished nearly all the commercial fertilizer nitrogen used in the United States. The work of the Fixed Nitrogen Research Laboratory in obtaining the scientific data necessary for the development of a domestic synthetic ammonia industry has been of inestimable value to the Nation from both the military and the agricultural standpoint.

Research by private and Federal agencies has resulted in the large scale conversion of synthetic ammonia into entirely acceptable low-cost concentrated fertilizers, such as ammonium nitrate (32 to 34 percent N) and urea (42 percent N). Ammonia solutions of ammonium nitrate or urea, furnishing low-cost nitrogen suitable for direct addition to mixed fertilizers containing superphosphates, have been developed and are widely used. Improvements in the oxidation of ammonia have lowered the cost of producing nitric acid for conversion into ammonium and sodium nitrates. Methods for the direct use of anhydrous ammonia as a fertilizer by adding it to irrigation water have been perfected.

2. Phosphates

From the beginning of the chemical-fertilizer industry, available phosphates have been made by low-cost methods involving the use of sulfuric acid. Even today the products of these methods—principally ordinary and double superphosphates—constitute more than 85 percent of the phosphate fertilizer used in the United States. Nevertheless, numerous improvements have been made in the old processes, new methods for the production of old materials have been devised, and

processes for the manufacture of new types of phosphates have been developed. Research by Federal agencies has paved the way for many of these advances and has contributed to the success of others.

An important advance in phosphate technology, based in part on research conducted in the Department of Agriculture, has been the large-scale development of the electric-furnace process for producing elemental phosphorus and concentrated phosphoric acid, first by private industry and later by the TVA. Also, commercial manufacture of phosphoric acid by means of the blast furnace has been achieved. Methods and equipment for the transportation and handling of elemental phosphorus and phosphoric acid have been perfected.

Double superphosphate, made with phosphoric acid manufactured by the sulfuric acid process, has been produced commercially in the United States for more than 35 years. Electric-furnace-made acid was first employed in quantity production of double superphosphate in the period 1914 to 1916 and its use for this purpose has expanded greatly since 1930. Methods have been developed for the granulation of superphosphates that facilitate the handling of these materials and their application to crops.

Processes have been developed for the production of several phosphates new to the fertilizer field. These include calcium metaphosphate (65 percent P_2O_5), potassium metaphosphate (55 percent P_2O_5 , 35 percent K_2O), and alpha phosphate (up to 30 percent P_2O_5). Commercial production of alpha phosphate, made by heating phosphate rock in the presence of silica and steam, was accomplished in 1944, and large-scale manufacture of a similar product by the TVA is expected. The Authority has produced more than 25,000 tons of calcium metaphosphate in experimental full-scale units.

Industrial developments in the processing and concentration of low-grade ores have vastly increased the Nation's reserve supply of utilizable phosphate rock. The outstanding accomplishment is the application of flotation principles in phosphate recovery.

3. Potash

The earlier work on potash was confined mostly to searches for sources of supply and studies of methods for recovering the material from brines, silicate and sulfate rocks, kelp, and other resources. Some 25 years ago the domestic industry was placed on a permanent though entirely inadequate basis by the recovery of potash from the brine of Searles Lake, Calif., an outstanding example of the industrial application of laboratory research. This operation is an important source not only of potash but also of boron for agricultural use. Processes have been developed for the recovery of potash from the brine of Salduro Marsh, Utah, and of potash and alumina from Utah alunite, as well as for the transformation of potassium chloride into potassium sulfate, potassium metaphosphate, potassium nitrate, and other agriculturally useful compounds.

The discovery of the New Mexico deposits and their commercial utilization rendered the United States completely independent of foreign sources of potash. Federal agencies as well as private interests participated in the research investigations underlying this development. The application of flotation to the separation of crystalline potassium chloride from the accompanying impurities was an important accomplishment.

4. Mixed Fertilizers

The importance of mixed fertilizers is emphasized by the fact that more than 75 percent of the commercially distributed plant food used in the United States is in the form of mixtures containing two or more of the major plant nutrients—nitrogen, phosphoric acid, and potash. The manufacture and use of mixed fertilizers involves numerous problems of chemical reactions and physical condition, and of the selection of materials and the formulation of mixtures for specific purposes. Changes in the types of available materials and in agronomic practices have necessitated a continuing program of research on mixed fertilizers. Such research has been fostered by private industry and governmental agencies for many years, with important results.

Progress has been made in the production of higher analysis mixtures by increasing the supply and use of high-analysis materials. Neutral mixtures that will not cause an increase in soil acidity, even with long-continued application, have been developed and are widely used. Problems arising from chemical reactions in the preparation of neutral mixtures and in the use of ammoniating solutions have been solved.

A measure of the relative power of fertilizer materials to cause "burning" of plants, known as the salt index, has been devised, and it has been shown that the burning effect of fertilizers is a function of their total soluble-salt content rather than their content of plant food.

The marked tendency of certain fertilizer materials, notably ammonium nitrate, and their mixtures to absorb moisture from the atmosphere causes serious difficulties in their handling, storage, and application to the soil. Research has pointed the way to the solution of these difficulties. Developments in the granulation and proper sizing of fertilizers have facilitated their distribution in the field and have favored the production of nonsegregating mixtures.

C. Agronomic Research

Researches on the agronomic phases of the fertilizer problem have been no less productive than those on the technological phases. The agronomic phases are far more numerous and complex, however, including, as they do, the relations of fertilizers not only to soils and plants but also to animals as well. Even today these relations, which involve many of the physical and biological sciences, for the most part are understood only imperfectly or not at all. Nevertheless, important

advances have been made in several directions. Owing, however, to their multiplicity, only the major accomplishments can be mentioned here.

1. Soil Resources and Crop Responses

The responses of soils and of crops throughout the Nation to applications of fertilizers have been determined by means of laboratory, greenhouse, and field studies. Extensive studies have been made of the supplies and character of the fertilizing elements in soils. Rapid chemical methods of estimating the availability of these elements have been developed and serve as useful guides to the fertility status of soils. The importance of the so-called minor plant-food elements, as boron, manganese, and copper, has been recognized, and considerable progress has been made in showing the soil areas in which marked deficiencies of these elements now occur. The removal of plant-food elements from soils by crops has been investigated. Correlation of the data with specific types of soils is a highly important phase of these investigations.

2. Efficiency of Different Sources of Plant Food

Much work has been done in determining the relative efficiencies of different sources of N , P_2O_5 , and K_2O in promoting the growth of various plants under different conditions. The investigations have included studies of water-soluble and water-insoluble phosphates, organic and inorganic (nitrate and ammoniacal) forms of nitrogen, and a number of potash salts.

3. Fertilizer Placement

Fertilizer placement with respect to seed and plant has been shown to be an important factor in crop stands and yields and in fertilizer efficiency. The most effective placements for different crops have been determined and have been widely adopted by farmers. Improved machines for applying fertilizers to the soil have been developed.

4. Diagnosis of Plant-Deficiency Symptoms

The visual symptoms characterizing deficiencies of the major and the minor plant nutrients have been determined for many economic plants. Thus, it is now possible to detect deficiencies and to correct most if not all of them during the growing season, either by soil treatments or by spray applications of the deficient elements directly to the leaves. The economic value of this work can hardly be overestimated.

D. Major Problems

1. Fertilizer Technology

Important problems of fertilizer technology include (a) the utilization of nitric acid in the production of available phosphates; (b) chemistry of phosphate systems; (c) production of improved and new types of superphosphates; and (d) formulation of high-analysis fertilizers of the 1-1-1 type having improved physical properties.

Low-cost nitric acid will be available in large quantity in postwar years. Substitution of nitric acid for sulfuric acid in the treatment of phosphate rock would be very desirable, as it would make use of a practically inexhaustible source of acid—the nitrogen of the atmosphere. This source supplies in itself a major plant-food element. Much work has been done on this subject, but as yet a satisfactory solution of the problem has not been obtained.

Progress has been made in the study of the chemistry of the systems involved in the manufacture of various phosphate fertilizers, but much work remains to be done. Complete information is needed as a basis for the improvement of existing processes and the development of new procedures for the production of available phosphates.

Large-scale manufacture of phosphoric acid and elemental phosphorus by furnace methods offers the possibility of economical use of these products for the local manufacture of superphosphate containing 30 percent or more of P_2O_5 . Phosphate rock would be treated with mixtures of phosphoric and sulfuric acids in the same equipment used for making ordinary superphosphate. Superphosphate containing 30 percent of P_2O_5 can be used as the sole source of P_2O_5 in all the practically useful grades of high-analysis fertilizers. An economical process for the direct manufacture of granular superphosphate in a continuous operation is needed. A practicable process for the removal of fluorine from superphosphate would eliminate much, if not all, of the reversion of available P_2O_5 that often occurs when superphosphate is mixed with alkaline materials.

Poor physical condition is commonly found in mixed fertilizers of the 1-1-1 type, which contain 30 percent or more of plant food, owing largely to the adverse effects of the nitrogen compounds used. Development of mixtures of this type having satisfactory physical properties would have an important effect in promoting the use of high-analysis fertilizers.

2. Fertilizer Use

The following are among the more important problems relating to fertilizer use: (a) Fertilizer requirements of different rotations and farming systems as related to the soil type and climatic factors; (b) determination of the plant-nutrient status of various soils under different systems of soil management and the relation to fertilizer requirements; (c) the interrelations of liming and use of fertilizers, with special reference to the influence of liming on the availability of phosphates and the conservation of soil and applied potash; (d) crop requirements for minor elements as related to soil types; and (e) the influence of fertilizers on the nutritive value of crops.

The more efficient use of fertilizers, especially of our phosphate and potash resources, depends in large measure upon more complete information on the first three points. What are the fertilizer requirements of a livestock system of farming on Cecil sandy loam of the

Piedmont as compared with the cotton-corn system? Are the requirements materially different on Cecil and Davidson soils? Of course there is considerable information bearing on such questions, but there is great need for additional research to support our various land-use programs.

Limited data are available to show the influences of certain farming systems, including fertilizer practices, on the plant-nutrient status of soils. Such data for the most part have been obtained from experimental plots. Very little attention has been given to a thorough study of farms and of the data related to the soil type and farming system. Work that has been done indicates that such studies would result in more efficient use of fertilizers and in better crop production.

Liming and fertilizer interrelations are of major importance on soil-conserving crops as well as row crops. The efficiency of phosphate fertilizers can be doubled and potash losses reduced by the proper use of lime on some acid soils. These relations should be further developed and used in action programs involving the use of lime and fertilizers.

The need for minor elements as related to crops and soil types should be carefully studied as well as the influence of fertilizers on the nutritive value of crops. Work on these subjects is progressing but could well be materially expanded. Progress in the more effective use of lime and fertilizers will depend to a considerable extent on the development of an adequate research program.

FERTILIZER CONTROL

The first practical law providing for official inspection of fertilizers was enacted in Massachusetts in 1873. Today all the States have fertilizer-control laws, with the exception of Nevada, which used only 200 tons of commercial fertilizer in the fiscal year 1943. There are no Federal laws providing for the registration, inspection, and quality control of fertilizers.

All the State laws require the registration of brands and grades of fertilizers. Also, they require guarantees of the percentages of major plant foods—nitrogen, phosphoric acid, and potash—and provide penalties for failure to meet the guarantees. In some instances, guarantees of other constituents are required or permitted, and it is necessary for the bag or tag to carry certain information relating to filler and to the character of the fertilizer. Many of the State laws have requirements as to the minimum quantity of total plant food that can be guaranteed in a mixed fertilizer or fertilizer material. Variations among the States in certain phases of the laws can be attributed largely to differences in the character of the agriculture and in the soil and crop requirements for fertilizer. Thus the laws can be, and usually are, adapted to the specific needs of the individual States.

Funds for operating the fertilizer-control laws are obtained chiefly from tonnage or brand taxes, or both and, in a few instances, from license fees. These taxes and fees vary among the States, as do the fines and other penalties assessed for failures to meet plant-food guarantees and for other violations. Likewise, there is variation as to the allowance for nonpenalizable deficiencies in guarantees.

With respect to tags, bag labeling, permissible grades, and guarantee specifications, there is a growing trend toward uniformity of the State laws on a regional basis. This uniformity is highly desirable, as it makes for better administration of the laws and favors simplification of operations. It also reduces the costs in the many plants that ship their products across State lines. Further increase in regional uniformity of the laws should be encouraged.

Satisfactory operation of fertilizer-control laws necessitates, among other things, the use of standardized, precise methods of sampling and chemical analysis. The development of such methods has been one of the chief functions of the Association of Official Agricultural Chemists from the time of its organization in 1884. Since that time the association has played a highly important part in the development and administration of fertilizer-control laws. Membership in the association is automatically composed of all State and Federal chemists engaged directly or indirectly in work pertaining to agriculture and to certain other phases of the public welfare. Nearly all State laws specify the use of the A. O. A. C. methods of sampling and analysis in official fertilizer

inspections. Also, these methods, especially the analytical procedures, are commonly used in factory-control work throughout the fertilizer industry.

As a rule there is close cooperation between the control officials and the State agricultural experiment stations in the formulation of fertilizer laws and in the solution of enforcement problems involving questions of the use and the agronomic value of fertilizers. In 11 States the administration of the control laws is in the hands of staff members of the agricultural experiment stations. In most of the others the responsible official is the commissioner or another member of the State department of agriculture.

Fertilizer consumption in four States—Massachusetts, North Carolina, Indiana, and Texas—totaled 1,856,294 tons during the 1943 season, or nearly one-sixth of the total for the United States. The total number of samples analyzed was 8,887, which was at the rate of 1 sample for each 209 tons of fertilizer. Of these samples, 723 (8.1 percent) were found to be deficient with respect to guaranteed plant-food content beyond the limits permitted by the State laws. On the other hand, the average overrun in plant food for all samples in each State, in relation to the guaranteed content, ranged from 2.0 percent in Texas to 6.9 percent in Indiana. The details on fertilizer inspections for these widely separated States are given in table 11.

In general, the State fertilizer-control laws afford adequate protection not only to the consumer but also to the honest manufacturer. Experience with the laws has pointed the way to improvements, and for the most part these have been adopted. Furthermore, it is a comparatively simple matter to revise and amend the laws in line with the changing needs of the individual States.

TABLE 11.—*Results of official fertilizer inspections in four States, 1943 season*¹

State	Fertilizer consumption ²	Samples analyzed	Samples deficient beyond limits permitted by State law	Average plant-food overrun
	<i>Tons</i>	<i>Number</i>	<i>Percent</i>	<i>Percent of guarantee</i>
Massachusetts.....	77,804	1,176	5.3	4.7
North Carolina.....	1,262,063	5,513	10.4	³ 2.5
Indiana.....	361,599	1,573	5.1	6.9
Texas.....	154,828	625	1.1	2.0

¹ For years ending variously from June 30 to December 31, 1943.

² As reported in official State publications; tonnages directly distributed by governmental agencies not included.

³ Based on value in excess of value guaranteed.

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APPENDIX

TABLE 12.—Consumption of commercially distributed fertilizers and their plant-food content, 1900 to 1944¹

Year	Fertilizer	Plant-food content ²				Proportion of plant food	Plant-food ratio ³		
		Nitrogen	Phosphoric acid	Potash	Total		N	P ₂ O ₅	K ₂ O
	1,000 tons	1,000 tons	1,000 tons	1,000 tons	1,000 tons	Percent			
1900.....	2,730	62.0	246.2	86.5	394.7	14.5	1.0	4.0	1.4
1901.....	3,044	68	282	90	440	14.5	1.0	4.1	1.3
1902.....	3,084	70	284	96	450	14.6	1.0	4.1	1.4
1903.....	3,382	77	311	108	496	14.7	1.0	4.0	1.4
1904.....	3,704	84	344	122	550	14.8	1.0	4.1	1.5
1905.....	3,913	90	368	129	587	15.0	1.0	4.1	1.4
1906.....	4,249	99	391	144	634	14.9	1.0	3.9	1.5
1907.....	4,307	101	392	151	644	15.0	1.0	3.9	1.5
1908.....	4,449	107	400	160	667	15.0	1.0	3.7	1.5
1909.....	4,821	125	434	178	737	15.3	1.0	3.5	1.4
1910.....	5,547	145.9	499.2	211.0	856.1	15.4	1.0	3.4	1.4
1911.....	6,108	162	544	232	938	15.4	1.0	3.4	1.4
1912.....	5,852	157	521	222	900	15.4	1.0	3.3	1.4
1913.....	6,416	173	571	244	988	15.4	1.0	3.3	1.4
1914.....	7,194	216	662	237	1,115	15.5	1.0	3.1	1.1
1915.....	5,418	206	515	81	802	14.8	1.0	2.5	.4
1916.....	5,214	208	505	16	729	14.0	1.0	2.4	.8
1917.....	6,087	213	596	33	842	13.8	1.0	2.8	.2
1918.....	6,580	217	625	46	888	13.5	1.0	2.9	.2
1919.....	6,751	219	641	88	948	14.0	1.0	2.9	.4
1920.....	7,296	227.8	660.1	257.5	1,145.4	15.7	1.0	2.9	1.1
1921.....	4,977	159	443	189	791	15.9	1.0	2.8	1.2
1922.....	5,798	191	516	226	933	16.1	1.0	2.7	1.2
1923.....	6,571	230	591	237	1,058	16.1	1.0	2.6	1.0
1924.....	6,999	252	630	259	1,141	16.3	1.0	2.5	1.0
1925.....	7,503	278.9	680.0	282.6	1,241.5	16.6	1.0	2.4	1.0
1926.....	7,531	285.9	701.3	289.7	1,276.9	17.0	1.0	2.5	1.0
1927.....	7,074	281.5	667.0	268.1	1,216.6	17.2	1.0	2.4	1.0
1928.....	8,215	342.0	775.8	332.9	1,450.7	17.7	1.0	2.3	1.0
1929.....	8,208	352.1	774.0	338.2	1,464.3	17.8	1.0	2.2	1.0
1930.....	8,425	376.6	792.8	353.8	1,523.2	18.1	1.0	2.1	.9
1931.....	6,541	300.9	610.9	274.7	1,186.5	18.1	1.0	2.0	.9
1932.....	4,545	213.6	412.9	191.6	818.1	18.0	1.0	1.9	.9
1933.....	5,110	240.2	463.5	222.3	926.0	18.1	1.0	1.9	.9
1934.....	5,794	275.3	529.5	262.7	1,067.5	18.4	1.0	1.9	1.0
1935.....	6,532	311.8	596.5	306.6	1,214.9	18.6	1.0	1.9	1.0
1936.....	7,193	350.4	661.0	350.1	1,361.5	18.9	1.0	1.9	1.0
1937.....	8,386	411.5	773.3	416.0	1,600.8	19.1	1.0	1.9	1.0
1938.....	7,677	384.1	707.0	393.4	1,484.5	19.3	1.0	1.8	1.0
1939.....	7,818	398.2	717.7	409.1	1,525.0	19.5	1.0	1.8	1.0
1940.....	8,163	419.1	751.8	435.0	1,605.9	19.7	1.0	1.8	1.0
1941.....	8,477	458.1	782.1	464.8	1,705.0	20.1	1.0	1.7	1.0
1942.....	8,992	398.6	868.8	519.4	1,786.8	19.9	1.0	2.2	1.3
1943.....	10,733	505.0	1,047.1	641.6	2,193.7	20.4	1.0	2.1	1.3
1944 ⁴	11,568	623.0	1,137.8	641.7	2,402.5	20.8	1.0	1.8	1.0

¹ Including Hawaii and Puerto Rico.

² Whole numbers represent data believed not to be accurate to less than 1,000 tons.

³ See footnote 1, table 1.

⁴ Preliminary.

TABLE 13.—Fertilizer and plant-food consumption in the year ended June 30, 1943, and estimated proportion of the crop acreage fertilized and of the crop value obtained through the use of fertilizer in 1942, by regions and States

Region and State	All fertilizers			Plant-food content							Proportion of crop acreage fertilized through the use of fertilizers in 1942-1	Estimated proportion of the total value secured through the use of fertilizers in 1942-1		
	Mixed fertilizers	Separate materials	Total	Mixed fertilizers			Separate materials			Total			Average	Per acre of harvested crop-land, 1942
				Nitro-gen	Phos-phoric acid	Potash	Nitro-gen	Phos-phoric acid	Potash					
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Percent	Pounds	Percent		
New England	401,587	88,824	490,411	16,947	40,605	44,072	2,735	13,338	1,971	119,668	24.40	58.6	39	
Maine	217,120	12,281	229,401	10,058	2,017	27,023	268	2,333	119	61,818	26.95	87.9	44	
New Hampshire	19,690	9,687	29,377	683	2,171	1,909	160	1,691	97	6,711	22.84	29.2	33	
Vermont	29,374	14,643	44,017	626	3,322	3,331	101	2,996	62	11,138	25.30	17.4	27	
Massachusetts	65,905	23,252	89,157	2,639	6,367	5,775	992	3,160	569	19,502	21.87	75.6	79	
Rhode Island	13,428	2,472	15,900	524	1,399	1,225	74	374	30	3,626	22.81	119.0	82	
Connecticut	56,071	26,489	82,559	2,417	4,809	4,609	1,160	2,784	1,094	16,873	20.44	72.8	64	
Middle Atlantic	1,020,511	434,227	1,454,738	30,151	118,598	85,011	12,819	78,863	3,747	329,189	22.63	35.8	47	
New York	285,779	206,185	491,964	10,510	33,107	22,995	9,394	36,837	1,044	113,887	23.15	29.2	38	
New Jersey	189,475	23,111	212,586	6,949	21,051	16,859	1,141	2,579	694	49,273	23.18	115.3	76	
Pennsylvania	299,689	114,178	413,867	6,641	36,043	24,217	1,305	22,571	1,744	92,521	22.36	30.3	43	
Delaware	37,195	3,448	40,643	848	4,051	3,660	184	448	51	9,242	22.74	41.5	53	
District of Columbia	1,201	488	1,689	34	122	86	24	74	0	340	20.13	767.5	80	
Maryland	168,216	28,287	196,503	4,071	19,479	14,467	593	4,795	167	43,572	22.17	50.2	58	
West Virginia	38,956	58,530	97,486	1,098	4,745	2,727	178	11,559	47	20,354	20.88	25.7	18	
South Atlantic	3,332,693	1,102,224	4,434,917	104,588	307,697	213,021	73,517	90,205	23,962	812,990	18.33	55.5	78	
Virginia	356,645	180,534	537,179	9,522	38,518	23,432	3,882	29,467	247	105,068	19.56	42.9	71	
North Carolina	1,049,067	281,706	1,330,773	30,947	95,885	65,462	23,418	14,734	5,854	236,300	17.76	69.4	85	
South Carolina	585,218	232,268	817,486	17,498	55,713	35,698	20,058	6,152	9,333	144,452	17.67	50.5	72	
Georgia	760,056	328,704	1,088,760	22,422	74,942	47,884	21,940	35,405	3,311	205,904	18.91	37.8	75	
Florida	581,707	79,012	660,719	24,199	42,639	40,545	4,219	4,447	5,217	121,266	18.35	137.9	87	
East North Central	1,230,856	412,997	1,643,853	14,885	161,067	128,351	4,274	47,699	1,901	358,177	21.79	10.4	27	
Ohio	431,442	68,110	499,552	5,516	56,498	37,363	943	12,769	1,111	113,100	22.64	19.1	47	
Indiana	316,567	56,959	403,526	3,039	45,340	41,727	1,442	9,005	613	101,166	25.07	15.1	46	
Illinois	88,274	164,278	256,552	1,377	11,331	9,472	942	8,195	544	31,163	12.34	2.5	6	
Michigan	211,454	55,231	266,685	2,973	27,379	21,670	1,168	9,864	221	63,275	23.73	13.9	37	
Wisconsin	153,119	68,419	221,538	1,980	20,719	18,119	277	7,866	512	49,473	22.33	9.0	19	

West North Central	101,204	208,610	309,814	1,573	13,104	10,656	253	43,651	747	69,984	22.59	9	3	1
Minnesota.....	29,700	28,058	57,758	551	3,989	3,651	28	5,423	94	13,736	23.78	1.2	4	3
Iowa.....	31,231	34,291	65,522	367	4,003	3,227	10	6,440	148	14,195	21.66	9	3	3
Missouri.....	36,728	109,791	146,519	549	4,668	3,506	188	22,391	500	31,802	21.71	4.0	16	4
North Dakota.....	799	2,048	2,847	22	116	77	0	783	0	998	35.05	(2)	.3	.2
South Dakota.....	125	350	475	4	11	9	0	150	0	174	36.63	(7)	.1	.1
Nebraska.....	793	1,412	2,205	32	91	46	0	605	0	774	35.10	1	.2	.1
Kansas.....	1,828	32,660	34,488	48	226	140	27	7,859	5	8,305	24.08	.8	2	1
South Central	1,330,475	1,148,222	2,478,697	45,067	144,991	83,724	65,897	150,224	7,236	497,139	20.06	10.4	25	19
Kentucky.....	96,715	255,295	352,010	2,166	11,461	6,364	352	50,528	111	70,982	20.16	23.5	30	22
Tennessee.....	161,196	194,683	355,879	3,627	18,779	11,139	3,172	36,613	803	74,133	20.83	16.0	37	22
Alabama.....	471,674	262,718	734,392	17,829	49,384	30,564	15,061	31,378	1,149	145,365	19.79	34.2	63	45
Mississippi.....	241,924	247,886	489,810	9,387	22,620	12,774	3,019	13,331	1,922	91,255	18.63	19.9	36	36
Arkansas.....	102,793	61,253	164,046	3,444	11,945	8,234	5,549	4,528	2,248	36,848	22.46	8.1	28	27
Louisiana.....	122,538	78,958	201,496	4,007	15,084	7,377	9,342	4,351	781	40,942	20.32	16.8	42	22
Oklahoma.....	8,475	7,458	15,933	276	999	488	6	1,486	0	3,255	20.43	.4	2	.6
Texas.....	125,150	39,971	165,131	4,331	14,719	6,784	1,196	7,109	222	34,361	20.81	2.2	5	3
Western	182,457	311,078	493,515	13,063	18,280	11,344	34,426	30,731	3,067	110,911	22.47	5.2	8	11
Montana.....	486	4,482	4,968	28	119	11	1	1,979	0	2,138	43.04	.6	1	.7
Idaho.....	1,783	8,975	10,758	133	343	55	290	3,150	151	4,122	38.32	2.4	5	2
Wyoming.....	139	1,453	1,592	6	23	7	0	643	0	679	42.65	1.1	2	1
Colorado.....	2,453	5,669	8,122	129	361	130	176	2,104	27	2,927	36.04	.9	3	1
New Mexico.....	421	3,645	4,066	30	62	19	46	1,267	0	1,424	35.02	1.7	2	2
Arizona.....	4,184	10,976	15,160	384	685	60	1,192	1,546	0	3,867	25.51	6.6	7	3
Utah.....	401	3,117	3,518	17	60	21	97	1,188	0	1,383	39.31	1.5	7	1
Nevada.....	75	125	200	5	23	0	0	54	0	82	41.00	1.1	3	1
Washington.....	28,830	20,761	49,591	1,202	2,883	2,275	1,310	3,490	491	11,651	23.49	6.5	9	6
Oregon.....	11,877	23,139	35,016	625	1,280	991	1,596	3,953	456	8,901	25.42	5.8	6	8
California.....	131,788	228,736	360,524	10,504	12,441	7,775	29,718	11,357	1,942	73,737	20.45	15.5	21	19
Territories	104,479	54,904	159,383	10,344	7,821	12,527	9,485	892	2,528	43,597	27.35	93.6	79	52
Hawaii.....	42,883	51,611	94,494	4,880	3,349	6,737	8,869	874	2,401	27,110	28.69	281.9	95	28
Puerto Rico.....	61,596	3,293	64,889	5,464	4,472	5,790	616	18	137	16,487	25.41	44.6	75	43
Continental United States.....	7,599,763	3,706,182	11,305,945	226,274	804,342	576,179	193,921	454,711	42,631	2,298,058	20.33	13.3	20	18
Total, United States.....	7,704,242	3,761,086	11,465,329	236,618	812,163	589,706	203,406	455,603	45,159	2,341,655	20.42	13.6	20	18

1 Fertilizer Review, July-Sept., 1943.

* Less than 0.1 pound per acre.

TABLE 14.—Regional consumption of commercially distributed fertilizer, 10-year intervals, 1890 to 1940, and 1943

Region	1890		1900		1910		1920	
	1,000 tons	Per-cent	1,000 tons	Per-cent	1,000 tons	Per-cent	1,000 tons	Per-cent
New England.....	123.0	8.85	194.8	7.14	217.1	3.91	351.4	4.82
Middle Atlantic.....	360.5	25.92	726.0	26.59	852.9	15.38	1,017.3	13.94
South Atlantic.....	704.2	50.65	1,234.4	45.22	3,145.6	56.71	3,999.3	54.81
East North Central....	70.2	5.05	162.5	5.95	339.3	6.12	669.8	9.18
West North Central....	1.0	.07	4.8	.18	35.1	.63	114.8	1.57
South Central.....	128.0	9.21	354.4	12.98	827.8	14.93	943.4	12.93
Western.....	.5	.04	3.0	.11	48.9	.88	80.4	1.10
Hawaii and Puerto Rico.	3.0	.21	50.0	1.83	80.0	1.44	120.0	1.65
Total.....	1,390.4	100.00	2,729.9	100.00	5,546.7	100.00	7,296.4	100.00

Region	1930		1940		1943	
	1,000 tons	Percent	1,000 tons	Percent	1,000 tons	Percent
New England.....	366.8	4.35	303.9	3.72	432.0	4.02
Middle Atlantic.....	1,043.2	12.38	1,162.7	14.24	1,337.2	12.46
South Atlantic.....	3,857.7	45.79	3,486.5	42.71	4,462.7	41.58
East North Central.....	788.3	9.36	946.8	11.60	1,456.7	13.57
West North Central.....	109.7	1.30	123.4	1.51	190.4	1.77
South Central.....	1,811.0	21.50	1,520.6	18.63	2,110.7	19.67
Western.....	186.6	2.22	299.0	3.66	526.0	4.90
Hawaii and Puerto Rico.....	261.5	3.10	320.5	3.93	217.5	2.03
Total.	8,424.8	100.00	8,163.4	100.00	10,733.2	100.00

TABLE 15.—Percentage of all farms using fertilizers, 10-year intervals 1909 to 1939, and average consumption per farm when used, 1939

Region and State	Farms using fertilizers				Consumption per farm, 1939
	1909	1919	1929	1939	
	Percent	Percent	Percent	Percent	Tons
New England.....	60.9	49.8	54.7	46.6	4.6
Maine.....	66.6	46.9	61.2	55.4	6.8
New Hampshire.....	56.7	42.9	46.6	39.6	1.5
Vermont.....	58.2	50.1	47.9	46.8	2.3
Massachusetts.....	58.8	53.1	55.6	41.9	3.9
Rhode Island.....	62.7	56.3	56.4	51.3	5.2
Connecticut.....	58.1	55.9	55.1	41.7	5.4
Middle Atlantic.....	57.9	66.4	58.9	56.4	3.8
New York.....	52.8	58.8	51.0	51.3	4.2
New Jersey.....	70.7	76.7	66.6	58.3	11.3
Pennsylvania.....	59.2	71.3	62.6	64.1	3.2
Delaware.....	83.3	89.8	77.5	66.2	5.2
District of Columbia.....	35.5	56.9	69.2	63.1	3.6
Maryland.....	75.9	82.0	77.9	70.2	5.1
West Virginia.....	24.8	40.5	36.6	45.3	1.2
South Atlantic.....	74.2	85.0	80.9	82.5	4.2
Virginia.....	60.5	72.6	63.4	66.1	3.1
North Carolina.....	71.6	84.8	83.5	86.0	4.0
South Carolina.....	79.5	91.6	88.0	92.0	4.6
Georgia.....	81.2	90.2	84.8	89.6	3.6
Florida.....	59.6	53.6	67.0	67.6	10.0
East North Central.....	19.6	33.2	33.0	36.2	2.3
Ohio.....	43.7	64.5	59.0	62.1	2.5
Indiana.....	25.7	48.1	45.0	48.7	2.3
Illinois.....	4.4	9.5	7.1	8.9	3.9
Michigan.....	15.1	33.5	39.3	41.0	2.0
Wisconsin.....	1.7	4.1	14.2	17.9	1.4
West North Central.....	2.1	5.6	5.1	5.2	1.8
Minnesota.....	.9	1.7	4.8	3.6	1.9
Iowa.....	.8	1.5	4.7	3.0	1.9
Missouri.....	6.6	18.0	12.7	13.5	1.7
North Dakota.....	.2	.6	.4	.9	2.2
South Dakota.....	.2	.2	.1	.3	1.1
Nebraska.....	.3	.4	.3	.9	1.5
Kansas.....	.8	3.7	2.4	4.4	2.0
South Central.....	33.8	39.8	49.8	57.7	1.8
Kentucky.....	21.9	32.0	29.9	41.1	1.1
Tennessee.....	21.7	33.6	39.3	45.2	1.2
Alabama.....	62.1	68.5	80.7	84.8	2.7
Mississippi.....	28.7	26.2	48.3	61.2	1.7
Arkansas.....	10.3	17.8	30.3	25.5	1.2
Louisiana.....	18.3	27.8	41.1	52.5	1.6
Oklahoma.....	.3	1.3	2.0	3.4	.8
Texas.....	3.8	6.3	15.3	13.4	1.4
Western.....	6.3	10.7	10.2	16.0	4.5
Montana.....	.3	.8	.3	6.0	1.6
Idaho.....	.8	1.4	3.2	14.0	1.1
Wyoming.....	.3	.3	1.3	7.9	1.7
Colorado.....	1.2	2.0	1.2	5.1	1.4
New Mexico.....	2.3	4.9	2.3	3.7	2.1
Arizona.....	.4	1.3	3.6	3.7	1.0
Utah.....	2.6	4.0	.4	15.3	.7
Nevada.....	1.3	1.8	1.0	3.0	1.2
Washington.....	3.2	5.5	11.8	13.4	2.1
Oregon.....	6.3	11.2	8.2	14.2	2.1
California.....	8.5	14.0	11.8	21.3	8.2
United States.....	28.7	35.2	35.6	38.3	3.0

TABLE 16.—Fertilizer used on principal crops, 1929, 1938, and 1942¹

Crop	1929		1938		1942	
	Consumption	Proportion of total consumption	Consumption	Proportion of total consumption	Consumption	Proportion of total consumption
	<i>Tons</i>	<i>Percent</i>	<i>Tons</i>	<i>Percent</i>	<i>Tons</i>	<i>Percent</i>
Cotton.....	2,230,000	28.0	1,462,000	19.3	1,460,623	14.6
Corn.....	1,650,000	20.7	1,636,000	21.6	2,203,900	22.0
Small grains.....	1,105,000	13.8	1,087,000	14.3	1,407,500	14.1
Tobacco.....	546,000	6.8	505,000	6.7	536,400	5.3
Potatoes.....	675,000	8.5	560,000	7.4	708,650	7.1
Sweetpotatoes.....	115,000	1.4	133,000	1.8	148,700	1.5
Hay.....	165,000	2.1	312,000	4.1	704,850	7.1
Pasture.....	(²)	.....	161,000	2.1	583,850	5.8
Vegetables.....	420,000	5.3	323,000	4.3	894,050	8.9
Fruits.....	340,000	4.3	339,000	4.5	667,100	6.7
Other crops.....	729,000	9.1	1,053,000	13.9	691,933	6.9
Total.....	7,975,000	100.0	7,571,000	100.0	10,007,556	100.0

¹ Fertilizer Review, July-Sept. 1943.² No estimate, very low.TABLE 17.—Liming materials reported used on soils in the United States, 1929, 1932, 1935, and 1938 to 1943¹

Region and State	1929	1932	1935	1938	1939	1940	1941	1942	1943
	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>
New England.....	107.5	94.8	64.8	175.2	221.3	256.9	261.8	316.2	237.1
Maine.....	8.3	4.8	5.7	42.0	44.2	56.8	67.7	68.1	63.6
New Hampshire.....	5.5	4.1	2.2	14.1	18.4	27.2	27.2	27.7	16.3
Vermont.....	8.6	3.6	5.7	24.2	35.6	51.3	42.0	93.0	68.5
Massachusetts.....	56.3	46.0	25.2	52.9	57.8	53.6	54.4	59.4	37.5
Rhode Island.....	1.3	1.3	1.9	6.0	7.2	8.0	9.7	9.1	6.6
Connecticut.....	27.5	35.0	24.1	36.0	58.1	60.0	60.8	58.9	44.6
Middle Atlantic....	517.9	374.9	501.6	1,466.9	1,706.3	1,988.5	2,240.0	2,546.1	2,474.9
New York.....	185.0	110.9	122.4	334.0	471.0	540.0	694.0	579.0	521.8
New Jersey.....	48.3	35.2	50.2	93.7	94.7	97.4	97.4	112.7	160.6
Pennsylvania.....	225.2	186.9	245.1	665.9	705.7	814.4	887.4	1,198.3	1,121.0
Delaware.....	17.2	5.8	8.9	19.2	23.3	22.3	25.4	17.9	27.3
Maryland.....	28.8	28.8	59.7	100.0	98.6	126.1	129.3	141.3	194.2
West Virginia..	13.4	7.3	15.3	254.1	313.0	388.3	406.5	496.9	450.0
South Atlantic.....	127.0	115.2	277.8	776.9	1,139.0	1,519.4	1,531.6	1,743.1	1,572.2
Virginia.....	120.0	47.6	110.6	513.3	709.6	867.6	912.5	1,077.6	690.0
North Carolina.....	.....	44.7	75.9	144.4	206.3	307.9	372.9	326.9	544.0
South Carolina.....	.....	7.9	42.3	64.3	129.4	148.0	110.2	150.0	132.0
Georgia.....	.....	6.3	14.0	13.6	24.9	116.1	77.7	80.0	85.0
Florida.....	7.0	8.7	35.0	41.3	68.8	79.8	58.3	108.6	121.2
East North Central.	1,726.5	629.6	1,853.0	3,132.4	3,588.5	5,707.6	6,007.0	7,548.0	8,003.7
Ohio.....	237.4	102.6	176.2	318.4	430.9	813.9	1,145.4	1,420.1	1,520.6
Indiana.....	204.1	115.9	253.5	570.1	648.8	1,048.1	1,000.5	1,276.5	1,264.5
Illinois.....	950.0	139.5	523.3	1,600.8	1,788.1	2,749.6	2,674.7	2,750.0	3,773.0
Michigan.....	335.0	155.0	135.0	167.0	325.0	325.0	310.0	640.0	325.0
Wisconsin.....	.....	116.6	765.0	476.1	395.7	771.0	876.4	1,461.4	1,120.6

¹ Data compiled by C. E. Carter, Agricultural Adjustment Agency, War Food Administration.

TABLE 17.—*Liming materials reported used on soils in the United States, 1929, 1932, 1935, and 1938 to 1943*—Continued

Region and State	1929	1932	1935	1938	1939	1940	1941	1942	1943
	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>
West North Central.	653.7	266.0	372.9	757.9	926.1	2,512.3	2,778.8	4,057.1	4,098.4
Minnesota.....	17.9	6.6	13.0	37.4	44.1	64.8	123.8	339.9	300.0
Iowa.....	360.0	142.1	224.0	239.9	399.2	1,018.4	1,025.9	1,957.1	2,173.2
Missouri.....	236.9	104.7	122.5	440.4	441.2	1,383.0	1,558.8	1,694.0	1,483.0
Kansas.....	38.9	12.6	13.4	40.2	41.6	46.1	70.3	66.1	142.2
South Central.....	636.9	338.8	378.1	1,551.8	1,722.7	2,500.0	2,963.9	2,350.6	2,335.6
Kentucky.....	276.9	175.4	285.0	916.1	920.0	1,444.8	1,626.2	1,469.8	1,253.8
Tennessee.....	350.0	155.0	70.0	524.4	662.0	900.0	1,165.7	675.0	675.0
Alabama.....		5.3	19.0	40.4	44.2	64.1	84.0	68.7	192.6
Mississippi.....	10.0	2.4	4.1	9.7	48.5	11.9	23.2	49.7	64.0
Arkansas.....		.7		48.8	33.2	57.4	37.4	35.9	51.4
Louisiana.....				2.3	3.9	6.0	5.8	7.1	40.0
Oklahoma.....				8.5	10.6	12.4	19.3	42.1	55.9
Texas.....				1.6	.3	3.4	2.3	2.3	2.9
Western.....	37.0	21.1	29.9	45.1	47.0	48.9	33.2	43.6	69.2
Washington.....	4.0	8.5	8.3	9.2	11.5	12.4	5.7	12.4	17.9
Oregon.....	2.0	2.6	5.2	25.6	26.3	27.5	18.7	18.6	23.0
California.....	31.0	10.0	16.4	10.3	9.2	9.0	8.8	12.6	28.3
United States.....	3,806.5	1,840.4	3,478.1	7,906.2	9,350.9	14,533.6	15,816.3	18,604.7	18,791.1

TABLE 18.—*Estimated profitable annual use of plant food and liming materials in the United States in the postwar period under conditions of agricultural prosperity, by regions*¹

Region	Plant food ²				Liming materials ³
	Nitrogen	Phosphoric acid	Potash	Total	
	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>
New England.....	28,592	59,949	53,394	141,935	730,410
Middle Atlantic.....	72,793	290,128	108,348	471,269	5,933,584
South Atlantic.....	412,852	654,670	450,957	1,518,479	7,032,507
East North Central.....	81,931	453,715	348,923	884,569	14,302,394
West North Central.....	36,618	524,419	254,070	815,107	11,948,591
South Central.....	339,623	599,754	269,051	1,208,428	11,074,921
Western.....	113,567	133,344	16,663	263,574	357,787
United States ⁴	1,085,976	2,715,979	1,501,406	5,303,361	51,380,194

¹ Fertilizer use assumed to be at the most economic level consistent with 1940 prices for fertilizers and 85 percent of 1943 prices for farm products.

² Preliminary figures subject to revision; compiled from estimates furnished the Bureau of Agricultural Economics by the State production adjustment committees, except for Illinois in the East North Central States and North Dakota and South Dakota in the West North Central.

³ Data furnished by C. E. Carter, Agricultural Adjustment Agency, War Food Administration.

⁴ Not including the District of Columbia.

TABLE 19.—*Estimated profitable annual use of plant food in the United States in the postwar period under conditions of agricultural prosperity, compared with total consumption in the year ended June 30, 1943, by crops and regions¹*

Crop	Year	New England	Middle Atlantic	South Atlantic	East North Central	West North Central	South Central	Western	Total ²	Increase, postwar year over 1942-43
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Percent
Corn.....	1942-43	6,973	49,064	205,381	124,349	13,571	105,324	.....	504,662	115.1
	Postwar	11,452	65,030	304,987	249,143	202,136	252,071	2,835	1,085,654	
Cotton.....	1942-43	.....	.....	154,593	.....	1,749	162,338	1,548	320,228	63.3
	Postwar	.....	.....	243,863	.....	13,500	263,484	2,080	522,927	
Tobacco.....	1942-43	4,845	4,722	84,820	452	.....	12,222	.....	107,061	48.0
	Postwar	4,720	8,630	114,784	31,962	1,290	27,020	.....	158,406	
Potatoes.....	1942-43	56,898	49,519	32,559	16,980	3,174	14,477	10,429	184,036	55.4
	Postwar	61,415	84,410	39,849	33,137	17,933	28,425	20,785	285,954	
Sweetpotatoes.....	1942-43	.....	3,414	16,030	.....	.....	12,958	.....	32,402	98.2
	Postwar	.....	3,189	34,491	.....	135	26,418	.....	64,233	
Large-seeded legumes ⁴	1942-43	.....	4,560	33,466	10,963	5,385	47,984	.....	161,867	148.3
	Postwar	591	.....	58,724	35,868	5,269	16,898	397	153,609	
Sugarcane and sugar beets..	1942-43	.....	.....	8,097	8,833	3,391	7,457	7,360	19,649	169.3
	Postwar	3,250	89,596	71,990	112,037	24,406	33,903	23,010	52,923	
Small grains ⁵	1942-43	2,051	107,406	189,476	375,788	274,169	69,822	16,953	336,909	207.4
	Postwar	32,898	52,286	63,789	45,434	22,285	78,022	10,989	1,035,665	
Hay and pasture.....	1942-43	44,269	90,283	308,525	110,871	283,656	355,404	71,933	1,305,703	313.8
	Postwar	14,804	80,248	150,362	44,399	2,990	53,540	78,858	425,201	
All other crops ⁶	1942-43	17,437	109,661	215,683	68,967	13,512	128,128	125,581	678,969	59.7
	Postwar	119,668	328,849	812,990	358,177	69,984	497,139	110,911	2,297,718	
Total ²	1942-43	141,935	471,269	1,518,479	884,569	815,107	1,208,428	263,574	5,303,361	130.8
Increase, postwar year over 1942-43, percent.....	Postwar	18.6	43.3	86.8	147.0	1,064.7	143.1	137.6	130.8	.....

¹ Figures for postwar use are preliminary and subject to revision. They were compiled from estimates furnished the Bureau of Agricultural Economics by the State production adjustment committees, except for Illinois in the East North Central States and North Dakota and South Dakota in the West North Central, assuming fertilizer use to be at the most economic level consistent with 1940 prices for fertilizers and 85 percent of 1943 prices for farm products.

² Not including the District of Columbia.

³ Tobacco is included with all other crops for Indiana.

⁴ Soybeans, cowpeas, peanuts, and dry beans.

⁵ Wheat, oats, barley, rye, and buckwheat.

⁶ Rice, vegetables, fruits, nuts, seed crops, etc.

TABLE 20.—Wholesale prices of plant nutrients in various fertilizer materials, 1920 to 1944¹

Year	Nitrogen				Phosphoric acid			Potash		Sulfur
	Ammonium sulfate	Sodium nitrate	Ammonia solutions	Natural organics ²	Florida phosphate rock ³	Superphosphate, Baltimore	Double superphosphate, Baltimore ⁴	Muriate of potash	Sulfate of potash	
1920..	\$4.08	\$4.44	.....	\$8.71	\$0.264	\$1.24	.....	\$2.43	\$3.41	\$0.143
1921..	2.41	3.18	.....	4.11	.169	.81	.....	1.04	1.49	.138
1922..	2.52	3.24	.....	5.14	.089	.57	.....	.63	.90	.125
1923..	2.93	3.22	.....	5.25	.087	.55	.....	.59	.84	.125
1924..	2.50	3.31	.....	4.97	.066	.50	.....	.58	.86	.125
1925..	2.65	3.28	.....	4.88	.070	.60	.....	.58	.86	.134
1926..	2.52	3.27	.....	4.62	.090	.60	.....	.60	.85	.170
1927..	2.33	3.22	.....	5.25	.089	.54	.....	.65	.92	.156
1928..	2.27	2.83	.....	6.13	.089	.58	.....	.67	.96	.161
1929..	2.01	2.78	.....	5.22	.091	.61	.....	.67	.96	.161
1930..	1.79	2.49	.....	4.50	.091	.54	.....	.68	.97	.161
1931..	1.34	2.36	.....	2.90	.091	.49	.....	.68	.97	.161
1932..	1.02	1.86	.....	1.83	.091	.46	.....	.68	.96	.161
1933..	1.12	1.53	\$1.06	2.61	.089	.43	.....	.66	.86	.161
1934..	1.18	1.54	1.02	3.41	.090	.49	\$0.65	.49	.75	.161
1935..	1.13	1.47	1.07	3.38	.090	.49	.75	.42	.68	.161
1936..	1.17	1.55	1.05	3.52	.053	.48	.73	.46	.71	.161
1937..	1.32	1.64	1.17	4.49	.053	.51	.75	.51	.76	.161
1938..	1.36	1.68	1.22	3.52	.053	.49	.74	.52	.77	.156
1939..	1.33	1.68	1.22	3.72	.054	.48	.70	.52	.75	.143
1940..	1.37	1.68	1.22	3.55	.054	.52	.69	.52	.73	.143
1941..	1.41	1.69	1.22	4.05	.056	.55	.71	.52	.78	.143
1942..	1.43	1.74	1.22	4.70	.061	.60	.83	.52	.81	.143
1943..	1.42	1.75	1.22	4.82	.057	.64	.85	.52	.80	.143
1944..	1.42	1.75	1.03	4.82	.060	.64	.87	.52	.80	.143

¹ Average prices per unit of 20 pounds of nitrogen, phosphoric acid, potash, or sulfur, as the case may be, at producing points or ports in bulk carlots.

² Average in castor pomace, process tankage, fish scrap, cottonseed meal, and animal tankage.

³ 68 percent B.P.L. (bone phosphate of lime) or 31.1 percent total P_2O_5 . The average price of other grades in 1944 was as follows: 70 percent, \$0.070; 72 percent, \$0.084; 75 percent, \$0.107; and 77 percent, \$0.129.

⁴ The only available series of prices covering a period of years is for Baltimore, although Baltimore is not a producing point at present. A unit of P_2O_5 in double superphosphate at East Tampa, Fla., cost 62 cents in 1943, while a unit in ordinary superphosphate was about 10 cents less.

TABLE 21.—Statistics of phosphate rock in the United States, 1920 to 1944

Year	Sold or used by producers				Exports	Imports	Apparent consumption ¹
	Florida	Tennessee	Idaho, Montana, Utah, and Wyoming	Total			
	Tons	Tons	Tons	Tons	Tons	Tons	Tons
1920....	3,773,710	2,760,468	62,282	4,596,460	1,198,077	230	3,398,613
1921....	1,993,631	3,111,031	7,046	2,311,708	821,309	3,959	1,494,358
1922....	2,305,624	3,397,386	5,019	2,708,029	805,609	6,597	1,909,017
1923....	2,853,371	3,480,164	33,975	3,367,510	926,857	7,532	2,448,185
1924....	2,724,491	3,444,235	43,198	3,211,924	917,026	18,030	2,312,928
1925....	3,281,560	3,536,731	81,347	3,899,638	974,624	3,063	2,928,077
1926....	3,033,192	3,519,895	42,086	3,595,173	838,839	19,463	2,775,797
1927....	2,953,910	539,581	57,691	3,551,182	1,028,396	31,578	2,554,364
1928....	3,229,460	646,346	45,769	3,921,575	1,006,616	51,309	2,966,268
1929....	3,458,894	710,012	43,252	4,212,158	1,279,876	50,287	2,982,569
1930....	3,637,840	684,370	75,349	4,397,559	1,372,809	36,577	3,061,327
1931....	2,308,842	384,857	145,456	2,839,155	1,065,462	15,116	1,788,808
1932....	1,646,373	4216,906	48,453	1,911,732	686,599	14,540	1,239,673
1933....	2,392,458	3,374,020	22,672	2,789,150	928,546	8,652	1,869,256
1934....	2,653,654	4,477,066	43,945	3,174,665	1,112,712	.....	2,061,953
1935....	2,713,540	4,616,318	77,608	3,407,466	1,236,921	4,143	2,174,688
1936....	2,939,888	4,721,081	93,111	3,754,080	1,354,025	3,472	2,403,527
1937....	3,356,438	4,924,111	150,382	4,430,931	1,179,138	15,008	3,266,801
1938....	3,032,215	5,100,732	148,406	4,187,947	1,277,742	7,847	2,918,052
1939....	3,000,238	4,105,162	156,615	4,207,915	1,062,887	3,920	3,148,948
1940....	3,186,413	4,113,684	182,926	4,483,023	841,674	3,307	3,644,656
1941....	3,769,441	4,125,401	228,169	5,252,411	1,142,355	4,861	4,114,917
1942....	3,373,709	4,153,025	297,545	5,201,549	592,162	4,217	4,613,604
1943....	4,019,112	4,146,146	256,122	5,741,380	400,971	52,086	5,392,495
1944 ²	4,203,130	4,148,831	334,879	6,021,840	(?)	(?)	(?)

¹ Quantity sold or used by producers plus imports minus exports.² Includes small quantities from Kentucky and South Carolina.³ Includes a small quantity from Kentucky.⁴ Includes a small quantity of apatite from Virginia.⁵ Includes small quantities from South Carolina and Virginia.⁶ Preliminary.⁷ Data not available.

TABLE 22.—Production of superphosphates in the United States, 1929 to 1944

Year	Ordinary superphosphate ¹	Double superphosphate	Total
	Tons P ₂ O ₅	Tons P ₂ O ₅	Tons P ₂ O ₅
1929.....	710,700	34,900	745,600
1930.....	751,200	43,300	794,500
1931.....	455,100	22,700	477,800
1932.....	295,400	11,400	306,800
1933.....	449,900	13,300	463,200
1934.....	477,500	31,300	508,800
1935.....	490,200	41,000	531,200
1936.....	568,800	58,400	627,200
1937.....	728,400	76,400	804,800
1938.....	597,200	86,000	683,200
1939.....	632,600	125,500	758,100
1940.....	724,400	151,400	875,800
1941.....	808,900	146,300	955,200
1942.....	926,000	144,600	1,070,600
1943.....	1,140,600	132,400	1,273,000
1944.....	1,213,100	126,500	1,339,600

¹ Includes small quantities of wet-mixed base made by treating mixtures of phosphate rock and nitrogenous organic materials with sulfuric acid.

LIST OF CHARTS

PAGE

Crop response to complete fertilizer	3
Trends of crop yields and changes in plant-food content of soils under long cropping, with and without use of fertilizer	4
Influence of fertilization and liming on the yield and chemical composition of pasture in central Maine	6
Soil erosion and water losses as influenced by slope, crop cover, and fertilization	8
Fertilizer consumption	13
Distribution of fertilizer by the Tennessee Valley Authority	15
Distribution of fertilizer by the Agricultural Adjustment Agency	17
Distribution patterns of fertilizer usage	18
Trends in fertilizer consumption	22
Regional consumption and rate of application of liming materials	25
Plant food in surface foot of soil	27
Percent of income from livestock and acre value of crops	29
Relation between farm income and expenditures for fertilizers	31
The relation between expenditures for fertilizer and plant-food consumption	33
Wholesale price of fertilizer material	39
Price fluctuations in the fertilizer industry	42
Influence of concentration on the consumer cost of plant food in fertilizers	44
United States trade in nitrogenous chemical fertilizers, 1924 to 1942	51
United States trade in phosphate rock and phosphatic fertilizers, 1924 to 1942	52
United States trade in potassic fertilizers, 1924 to 1942	54
Production of chemical nitrogen and location of plants in North America	56
Production of phosphatic fertilizer materials	58
Production of potash and location of major plants	62

LIST OF TABLES

	PAGE
1. Plant-food consumption in Europe, average 1935 to 1937	19
2. Plant-food consumption by regions, 1941	20
3. Plant-food content of manure and fertilizer used on crops in several regions and certain States in these regions, 1941	28
4. Crop acreage and fertilizer use in relation to crop value per acre	30
5. Estimated fertilizer and plant food that would be purchased by farmers under certain circumstances	35
6. Estimated crop acreage and estimated profitable annual use of plant food in the United States in the postwar period under conditions of agricultural prosperity compared with data for the year ended June 30, 1943	37
7. Prices of plant foods in different countries, 1935 and 1938	41
8. Plant-food content of different classes of materials used in the manufacture of mixed fertilizers and the percentages of limestone and filler in mixed fertilizers, in certain years	45
9. United States capacity for production of chemical nitrogen	57
10. Estimated capacity for production of superphosphate in the United States	60
11. Results of official fertilizer inspections in four States, 1943 season	72
12. Consumption of commercially distributed fertilizers and their plant-food content, 1900 to 1944	81
13. Fertilizer and plant-food consumption in the year ended June 30, 1943, and estimated proportion of the crop acreage fertilized and of the crop value obtained through the use of fertilizer in 1942, by regions and States	82
14. Regional consumption of commercially distributed fertilizer, 10-year intervals, 1890 to 1940, and 1943	84
15. Percentage of all farms using fertilizers, 10-year intervals, 1909 to 1939, and average consumption per farm when used, 1939	85

16. Fertilizer used on principal crops, 1929, 1938, and 1942	86
17. Liming materials reported used on soils in the United States, 1929, 1932, 1935, and 1938 to 1943	86
18. Estimated profitable annual use of plant food and liming materials in the United States in the postwar period under conditions of agricultural prosperity, by regions	87
19. Estimated profitable annual use of plant food in the United States in the postwar period under conditions of agricultural prosperity, compared with total consumption in the year ended June 30, 1943, by crops and regions	88
20. Wholesale prices of plant nutrients in various fertilizer materials, 1920 to 1944	89
21. Statistics of phosphate rock in the United States, 1920 to 1944	90
22. Production of superphosphates in the United States, 1929 to 1944	90

CONTENTS

	PAGE		PAGE
Fertilizers and lime in the United States: Resources, production, marketing, and use	1	Fertilizer prices— <i>Continued.</i>	
Fertilizers and lime in the national economy	2	B. Retail prices	41
A. Agriculture	2	1. Changes in prices, 1900 to 1943	41
1. Crop production	2	2. Plant-food content and retail price	43
2. Soil productivity and improvement	2	3. Reducing the farm cost of plant food	43
3. Nutrition	5	Fertilizer and lime resources	46
4. Erosion control	7	A. Nitrogen	46
B. Industry and labor	9	B. Phosphates	46
1. Nitrogen	10	C. Potash	47
2. Phosphates	10	D. Sulfur	48
3. Potash	10	E. Liming materials	49
4. Mixed fertilizers	10	Foreign trade	50
5. Liming materials	10	A. Nitrogen	50
6. Freight movement	11	B. Phosphates	50
Fertilizer consumption	12	C. Potash	53
A. Commercial consumption, 1900 to 1944	12	Plant locations and production capacity	55
B. Distribution through Government aid, 1935 to 1944	14	A. Nitrogen	55
1. Tennessee Valley Authority	14	B. Phosphates	57
2. Agricultural Adjustment Agency	14	C. Potash	61
C. State and regional consumption	16	D. Mixed fertilizers	61
1. Fertilizer consumption by States	16	E. Liming materials	63
2. Trends in consumption... ..	21	F. Farmer cooperatives	63
D. Consumption by crops	23	Research	64
Consumption of liming materials	24	A. Governmental participation in relation to private industry	64
Factors influencing the demand for fertilizers	26	B. Fertilizer technology	65
A. Native soil fertility	26	1. Nitrogen	65
B. The farming system	26	2. Phosphates	65
C. Farm income	30	3. Potash	66
D. Fertilizer prices	32	4. Mixed fertilizers	67
E. Research and education	34	C. Agronomic research	67
Estimates of postwar demand for fertilizers and lime	35	1. Soil resources and crop responses	68
A. Commercial demand	35	2. Efficiency of different resources of plant food	68
B. Estimates of profitable use.. ..	36	3. Fertilizer placement	68
Fertilizer prices	38	4. Diagnosis of plant-deficiency symptoms	68
A. Wholesale price of fertilizer material	38	D. Major problems	68
1. Nitrogen	38	1. Fertilizer technology	68
2. Phosphates	38	2. Fertilizer use	69
3. Potash	40	Fertilizer control	71
4. Sulfur	40	Selected references	73
5. Comparison with foreign prices	41	A. Printed publications	73
		B. Processed publications	79
		Appendix	81
		List of charts	91
		List of tables	92

